

Schedule	iii
Abstracts	1
Author Index	

Sunday

Sunday	
Sunday, January 9, 2011, 12:30 PM - 3:40 PM	.1
HAD I Special: The Astronomical Contributions of the Herschel Family	.1
Sunday, January 9, 2011, 4:00 PM - 6:00 PM	.3
HAD II Special: Neptune after One Orbit: Reflections on the Discovery of a Planet	.3

Monday

Monday, January 10, 2011, 8:30 AM - 9:20 AM	5
Kavli Lecture: Cassini Eyes the Rings of Saturn	5
Monday, January 10, 2011, 9:00 AM - 6:30 PM	6
NANOGrav Posters	6
Kepler Posters	9
Gamma Ray Bursts	18
AGN, QSO, Blazars	21
Black Holes	46
Binary Stellar Systems, X-ray Binaries	48
Career Paths, Professional Development, and STEM Diversity	60
HAD III History Poster Papers	64
Dwarf Galaxies	69
Elliptical Galaxies	74
Galaxy Clusters	78
Large Scale Structure, Cosmic Distance Scale	88
Dark Matter & Dark Energy	90
Star Associations, Star Clusters - Galactic & Extra-galactic	93
Stellar Evolution, Stellar Populations	108
Stellar Atmospheres, Winds	114
The Sun	118
The Solar System	124
Instrumentation: Ground Based or Airborne	128
Education, Public Outreach, Citizen Science and Science Impact	136
Monday, January 10, 2011, 10:00 AM - 11:30 AM	143
Results from the First Year of Observations with the Cosmic Origins Spectrograph	143
Kepler I	145
HEAD: High Energy Processes in Star Formation	149
Binary Stellar Systems, X-ray Binaries	151
AGN, QSO, Blazars I	154
Hydrogen Epoch of Reionization Arrays (HERA): Progress and Planning	157
Gamma Ray Bursts	161
Galaxy Clusters: Intracluster Medium and Cluster Masses	163
Strategies for Addressing Harassment and Prejudice	166
HAD IV History of Astronomy	

Interstellar Medium: Dust Particles and Emission	
YSOs, Etc. I	
Starburst Galaxies	
Evolution of Galaxies I	
Computation: Learning, Simulating, Data Reduction	
Monday, January 10, 2011, 11:40 AM - 12:30 PM	
Chandra's First Decade (Plus) of Discovery	
Monday, January 10, 2011, 2:00 PM - 3:30 PM	
Super-Earths and Terrestrial Planets: Latest Results from the Kepler Mission	
Community Science with LSST	
Science Highlights from NASA's Astrophysics Data Analysis Program I	
The Low-Frequency Gravitational Wave Universe: Detection Prospects, Sources, and A	strophysics . 194
AGN, QSO, Blazars II	
White Dwarfs in Binaries and Interacting Systems	
Galaxy Clusters: Intracluster Medium and Cosmology	
Evolution of Galaxies II	
HAD V History of Astronomy	
Planetary Nebulae and Supernova Remnants	
YSO's Etc. II	
Interstellar Medium: HII Regions	212
Star formation in Extragalactic Systems	215
Monday, January 10, 2011, 3:40 PM - 4:30 PM	217
Pierce Prize: Dark Matter and Black Holes Over Cosmic Time	217
Monday, January 10, 2011, 4:30 PM - 5:20 PM	218
Exoplanets: Misaligned, Migratory, Metallic, and Mini	

Tuesday

Tuesday, January 11, 2011, 8:30 AM - 9:20 AM	219
The Virgo Cluster: New Results from New Surveys	219
Tuesday, January 11, 2011, 9:00 AM - 6:30 PM	219
Dark Energy Survey	219
Radio Sky Surveys Project with the Allen Telescope Array	221
The Milky Way, The Galactic Center	
Stars, Cool Dwarfs, Brown Dwarfs	
Cosmic Microwave Background	
Starburst Galaxies	245
Spiral Galaxies	251
The Center for Astronomy Education (CAE) Collaboration of Astronomy Teaching Schol Program: A Year-Three Update	ars (CATS) 260
Astronomy Education and Research in Grades K-12	
Cosmology	272
Interstellar Medium, Dust	278
Interstellar Medium, Molecular Clouds, HII Regions	
LSST Posters	
Exoplanet Detection: Techniques & Observations	
Instrumentation: Space Missions	
Exploring the Far-IR/Sub-mm with the Herschel Space Observatory	
Planetary Nebulae and Supernova Remnants	
Emerging Results on an Extreme Binary, Epsilon Aur	
Star Formation	
Planck Poster Session	
Tuesday, January 11, 2011, 10:00 AM - 11:30 AM	
Kepler II	
Exploring the Far-IR/Sub-mm with the Herschel Space Observatory	
Radio Sky Surveys Project with the Allen Telescope Array	
Large Scale Structure, Cosmic Distance Scale	
The Dark Energy Survey	
Science Highlights from NASA's Astrophysics Data Analysis Program II	
M31, M32 & S4G Spirals	
Practical Tools & Techniques for Educators	
HAD VI History of Astronomy	
Evolution of Galaxies III	

AGN, QSO, Blazars III
Galaxy Clusters: Surveys and AGN
Cosmology I
Pulsars, Neutron Stars I411
Interstellar Medium: Molecular Gas414
Interstellar Medium, Cosmic Rays and Magnetic Fields416
Tuesday, January 11, 2011, 11:40 AM - 12:30 PM
Early Astrophysics Results from Planck419
Tuesday, January 11, 2011, 2:00 PM - 3:30 PM
Exoplanet Detection: Transits
Habitability of a Terrestrial Planet
Surveys and Large Programs
HEAD: New Radio Insights in High Energy Phenomena429
Emerging Results on the Extreme Binary, epsilon Aurigae431
Gravitational Lenses and Gravitational Waves432
Multiple Cool and Brown Dwarfs434
Galaxy Clusters: Lensing and S-Z Effect437
The Center for Astronomy Education (CAE) Collaboration of Astronomy Teaching Scholars (CATS) Program: A Year-Three Research Update
Evolution of Galaxies IV
AGN, QSO, Blazars IV
Cosmology II450
Stellar Winds, Jets, and Ejecta
Evolution of Galaxies V456
Pulsars, Neutron Stars II
Tuesday, January 11, 2011, 3:40 PM - 4:30 PM
Warner Prize: Millisecond Pulsars: The Gifts that Keep on Giving
Tuesday, January 11, 2011, 4:30 PM - 5:20 PM
A New View of the High Energy Gamma-Ray Sky with the Fermi Gamma-Ray Space Telescope462

Wednesday

Wednesday, January 12, 2011, 8:30 AM - 9:20 AM	
The First Supermassive Black Holes	
Wednesday, January 12, 2011, 9:00 AM - 6:30 PM	
Observing with ALMA	
Early Science with EVLA	
Early Results from WISE	
Surveys and Large Programs	
Evolution of Galaxies	
Pulsars, Neutron Stars	
Supernovae	
Evolved Stars, Cataclysmic Variables, Novae, Wolf-Rayet Phenomena	
Circumstellar Disks	
YSOs, Very Young Stars and Friends	
White Dwarfs	
Variable Stars	
Extrasolar Planets: Characterization and Theory	
Computation, Data Handling, Image Analysis	
Intergalactic Medium, QSO Absorption Line Systems	
Undergraduate Astronomy Education and Research	
Gravitational Lenses and Gravitational Waves	
Catalogs	
Astrobiology & Laboratory Astrophysics	
Wednesday, January 12, 2011, 10:00 AM - 11:30 AM	
Early Results from the Wide-field Infrared Survey Explorer	
Exoplanet Detection: Imaging, Interferometry	
Supermassive Black Holes	
Early Science with the Expanded Very Large Array	
Ultraviolet Astronomy in the New Detector Era	
The Solar System	611
Stars, Cool Dwarfs, Brown Dwarfs	615
Supernovae I - Type Ia	618
Evolution of Galaxies VI	
AGN, QSO, Blazars V	
Stellar Evolution, Stellar Populations and Variable Stars	

Nearby Galaxy Clusters, Groups, and Ellipticals630
Cosmic Microwave Background
Wednesday, January 12, 2011, 11:40 AM - 12:30 PM
Heinemann Prize: The Inner Space/Outer Space Connections: Dark Matter, Dark Energy, Inflation and All That
Wednesday, January 12, 2011, 2:00 PM - 3:30 PM635
Observing with ALMA635
Exoplanet Detection: Many Techniques637
The Sun, the Earth & Astrobiology639
Joint Astrophysics and Planetary Science Studies From the Outer Solar System
Cluster Cosmology with Optical and SZ data643
Circumstellar Disks I and Sedna646
The Milky Way, The Galactic Center648
Supernovae II - Type Ia651
Evolution of Galaxies VII
AGN, QSO, Blazars VI657
Star Associations, Star Clusters - Galactic & Extra-galactic I661
Stellar Populations and Kinematics of Dwarf and Irregular Galaxies
Wednesday, January 12, 2011, 3:40 PM - 4:30 PM
Cannon Prize: Stellar Archaeology: New Science with Old Stars
Wednesday, January 12, 2011, 4:30 PM - 5:20 PM
Rossi Prize: Exploring the Very High Energy Sky with H.E.S.S.

Thursday

Thursday, January 13, 2011, 8:30 AM - 9:20 AM	
Exoplanets: New Approaches to their Discovery and Characterization	
Thursday, January 13, 2011, 9:00 AM - 2:00 PM	
Extrasolar Planets	
Galaxies, Galaxy Clusters and Friends	673
Education and Outreach	
High Energy, Cosmology and Other Topics	
Instrumentation, Surveys and Data	
Stars, Star Formation and Associated Topics	712
The Solar System II	733
The Sun II	735
Thursday, January 13, 2011, 10:00 AM - 11:30 AM	737
Exoplanet Detection: Radial Velocities	737
Exoplanet Atmospheres - Modeling and Observations	738
Dark Matter & Dark Energy	742
Black Holes	745
Astronomy Education Research	747
Circumstellar Disks II	751
Evolution of Galaxies VIII	753
AGN, QSO, Blazars VII	757
Star Associations, Star Clusters II	
Supernovae III	762
The Role of Environment in Galactic Star Formation	
Intergalactic Medium, QSO Absorption Line Systems	767
Instrumentation: Ground Based	
Thursday, January 13, 2011, 11:40 AM - 12:30 PM	773
Addressing Unconscious Bias: Steps toward an Inclusive Scientific Culture	773
Thursday, January 13, 2011, 2:00 PM - 3:30 PM	773
Exoplanet Systems - Characterization and Dynamics	
The Formation of Very Massive Stars	777
Spiral Galaxies	778
Exoplanet Atmospheres - Observations and Modeling II	
Circumstellar Disks III	
Education and Outreach Beyond IYA	

Evolution of Galaxies IX	
Elliptical Galaxies: S4G, LIERs, Black Holes	791
Supernovae IV	794
Origin and Evolution of the Milky Way Satellites	797
Instrumentation: Space Missions	799
The Intergalactic Medium as seen by FIREBALL & CW1	802
Star Associations, Star Clusters III	804
Thursday, January 13, 2011, 3:40 PM - 4:30 PM	
Berkeley Prize: Kepler: Opening New Doors in Astronomy	806

Abstracts

Sunday, January 9, 2011, 12:30 PM - 3:40 PM

HAD I Special: The Astronomical Contributions of the Herschel Family Special Session *Room 613/614*

The Herschels: A very fashionable scientific family

Emily Winterburn¹

¹University College London, United Kingdom. 12:30 PM - 1:15 PM

Room 613/614

What is special about the Herschel family? It is a family that has attracted the attention of historians of science for many years and has done so for a number of reasons. Some simply marvel at the family's ability to have produced generations upon generation of great men and women of science. Others have highlighted the work of individuals within the family and how their work changed the way astronomy was done, what it was about, and then later did the same for science as a whole. The unusually high status enjoyed by Herschel women, Caroline Herschel in particular, has not escaped notice, though I will here question some of the conclusions drawn about her motivations. Most of all, however I will argue in this paper, they should be interesting to a modern audience for the way in which they managed time and again, generation on generation, to make science fashionable and popular.

In this paper I will look at three generations of this family - from William and Caroline discovering comets and planets in the late eighteenth century, through John and his claim that society needs science to be properly civilised, to John and Margaret's children and their varied takes on the relationship between astronomy, science and the public. I will look at the role astronomy played in each of their lives, how they were taught and taught each other and how in each generation they managed to make their work the talk of the town.

The Herschels and the Nebulae

Robert W. Smith¹

¹University of Alberta. 1:15 PM - 1:40 PM Room 613/614

An innovative observer, theorist and telescope builder, William Herschel is now generally recognised as one of the greatest astronomers of all time. In this paper I will argue that to set Herschel's career correctly into context it is essential to see him in addition as a natural philosopher (as the term `natural philosopher' was understood around 1800). In examining Herschel as a natural philosopher, I will focus on his shifting views on the nature of the nebulae, views I will also contrast and compare with those of his son John Herschel.

Herschel's 20ft Telescope at the Smithsonian David H. DeVorkin¹

¹Smithsonian Inst.. 1:40 PM - 1:55 PM Room 613/614 The tube and one of the mirrors from the original Herschel 20-foot telescope have been on display at the National Air and Space Museum since September 12, 2001. Approximately 3,000 visitors walk past it each day, inspecting how William and Caroline jointly operated the telescope in their garden. This presentation will recount how the telescope was brought to NASM, and prepared for exhibition. We will also discuss a bit of what we've learned about the telescope's history from developing this display.

William Herschel's Explorations of the Conditions for Extraterrestrial Life

Marvin Bolt¹ ¹Adler Planetarium. 2:10 PM - 2:35 PM Room 613/614

William Herschel's notion of life on the sun has been described as one of his stranger ideas. A more careful look, though, supports his declaration to have founded his view "upon astronomical principles" (broadly construed) as opposed to resembling the musings of "fanciful poets." In particular, we'll explore how contemporary concepts of geology and heat informed William's defense of solarians, and see how a few of John Herschel's methodological comments provide insight into William's reasoning.

Planetary Observations by William Herschel

Woodruff T. Sullivan, III¹ ¹Univ. of Washington. 2:35 PM - 3:00 PM *Room 613/614* William Herschel was a co

William Herschel was a constant observer of the planets and ~40% of his publications are concerned with every known object in the solar system; yet historians have paid little attention to this aspect of his career. In this paper I will summarize his major solar system findings (including the moon and sun) and, for a few key cases, discuss his observational techniques and interpretations. I will also argue for significant connections between Herschel's planetary and solar work and his more familiar work on the sidereal universe.

Who Invented the Word Asteroid: William Herschel or Stephen Weston?

Clifford J. Cunningham¹

¹James Cook University. 3:00 PM - 3:15 PM Room 613/614

William Herschel made the first serious study of 1 Ceres and 2 Pallas in the year 1802. He was moved by their dissimilarities to the other planets to coin a new term to distinguish them. For this purpose he enlisted the aid of his good friends William Watson and Sir Joseph Banks. Watson gave him a long list of possible names, most of which sound quite ludicrous. With a lifetime of experience classifying and naming newly found objects in nature, Banks became the man both Erasmus Darwin (in 1781) and William Herschel (in 1802) turned to for sage advice in developing a new descriptive language. In the case of Ceres and Pallas, Banks turned the task over to his friend, the noted philologist Stephen Weston FRS. It has recently been stated by a noted British historian that it was Weston- not Herschel- who coined the term "asteroid" to collectively describe Ceres and Pallas. This claim is investigated, and parallels are drawn in the use of neologism in astronomy and botany.

John Herschel's Graphical Method Thomas L. Hankins¹

¹University of Washington. 3:15 PM - 3:40 PM

Room 613/614

John Herschel's Graphical Method

In 1833 John Herschel published an account of his graphical method for determining the orbits of double stars. He had hoped to be the first to determine such orbits, but Felix Savary in France and Johann Franz Encke in Germany beat him to the punch using analytical methods. Herschel was convinced, however, that his graphical method was much superior to analytical methods, because it used the judgment of the hand and eye to correct the inevitable errors of observation.

Line graphs of the kind used by Herschel became common only in the 1830s, so Herschel was introducing a new method. He also found computation fatiguing and devised a "wheeled machine" to help him out. Encke was skeptical of Herschel's methods. He said that he lived for calculation and that the English would be better astronomers if they calculated more.

It is difficult to believe that the entire Scientific Revolution of the 17th century took place without graphs and that only a few examples appeared in the 18th century. Herschel promoted the use of graphs, not only in astronomy, but also in the study of meteorology and terrestrial magnetism. Because he was the most prominent scientist in England, Herschel's advocacy greatly advanced graphical methods.

Sunday, January 9, 2011, 4:00 PM - 6:00 PM

HAD II Special: Neptune after One Orbit: Reflections on the Discovery of a Planet Special Session *Room 613/614*

The Discovery of Neptune: Why It Mattered in 1846 and Why It Still Matters

Robert W. Smith¹ ¹University of Alberta. 4:00 PM - 4:20 PM Room 613/614

The discovery of Neptune is one of the most well-known events in the history of nineteenth century astronomy as well as one of the most analyzed. Given the ferocious battle for priority that the optical discovery provoked, it is not surprising that much of the literature on the discovery has focused narrowly on issues around the appropriate amount of credit to be handed out to the main protagonists for the theoretical and optical discoveries of the planet. In this paper I will instead seek to put the discovery of Neptune and the events surrounding it into the broad context of mid-nineteenth century science to explain why it was seen to matter so much at the time and why it still matters today.

The Life and Times of John Couch Adams, from 1819 to 1847

Brian M. Sheen¹

¹Roseland Observatory, United Kingdom. 4:20 PM - 4:40 PM Room 613/614 John Couch Adams was born in 1819 in th

John Couch Adams was born in 1819 in the middle of Cornwall, the most remote and isolated county in England. How he progressed from there to Cambridge University to become one of the finest mathematicians of the nineteenth century fills everyone who studies him with awe. Tragically what should have been his greatest triumph - the discovery of a new planet - was marred by mishap, controversy and unanswered questions.

This presentation examines one of the first of these questions and provides new answers based on recently revealed evidence. The Astronomer Royal of the day was attempting to support Adams and as part of that support asked if his analysis took into account changes in radius vector of Uranus. Adams did not reply and the rest as they say is history.

However there is far more to the question than a non-existent letter - this in itself turns out to be not

exactly true. Further analysis of the orbits and a letter in French - not been translated before reveals Adams had a more profound understanding of the situation than some later authors have given him credit.

Neptune's Discovery: Le Verrier, Adams, and the Assignment of Credit William Sheehan $^{\rm 1}$

¹Child and Adolescent Behavioral Health Services. 4:40 PM - 5:00 PM

Room 613/614

As one of the most significant achievements of 19th century astronomy, the discovery of Neptune has been the subject of a vast literature. A large part of this literature--beginning with the period immediately after the optical discovery in Berlin--has been the obsession with assigning credit to the two men who attempted to calculate the planet's position (and initially this played out against the international rivalry between France and England). Le Verrier and Adams occupied much different positions in the Scientific Establishments of their respective countries; had markedly different personalities; and approached the investigation using different methods. A psychiatrist and historian of astronomy tries to provide some new contexts to the familiar story of the discovery of Neptune, and argues that the personalities of these two men played crucial roles in their approaches to the problem they set themselves and the way others reacted to their stimuli. Adams had features of high-functioning autism, while Le Verrier's domineering, obsessive, orderly personality--though it allowed him to be immensely productive--eventually led to serious difficulties with his peers (and an outright revolt). Though it took extraordinary smarts to calculate the position of Neptune, the discovery required social skills that these men lacked--and thus the process to discovery was more bumbling and adventitious than it might have been. The discovery of Neptune occurred at a moment when astronomy was changing from that of heroic individuals to team collaborations involving multiple experts, and remains an object lesson in the sociological aspects of scientific endeavor.

"These Frenchmen fly at one like wild cats": The French Press Attacks on British Claims for a Role in the Discovery of Neptune

Craig B. Waff¹

¹*Air Force Research Laboratory.* 5:00 PM - 5:20 PM

Room 613/614

In a letter to the editor of the Athenaeum (a weekly British intellectual periodical) that appeared in its 3 October 1846 issue, John Herschel revealed that a young Cambridge fellow, John Couch Adams, had performed calculations, as yet not published or otherwise publicly announced, that were similar to those made by Urbain Jean Joseph Le Verrier in predicting a position for a hypothetical planet disturbing the motion of Uranus. As is well known, a plea from Le Verrier led Johann Gottfried Galle to search for and optically discover, on 23 September 1846, a transuranian object near Le Verrier's predicted position. Shortly after the appearance of Herschel's letter, he and Adams, as well as Cambridge Observatory director James Challis and Astronomer Royal George Airy, became the targets of an intense month-long public attack by various Parisian newspapers and magazines, which perceived a British attempt to "steal" the discovery of the new planet, soon to be named Neptune. It was this attack that led to the despairing comment in Herschel's diary that appears in the title of my talk. Although this attack has been frequently mentioned by commentators on the controversies surrounding the discovery of Neptune, the actual French publications have virtually never been examined in detail. An analysis of some of these articles, as well as British responses to them, is presented here.

The Neptune Affair: American Mathematicians Find the World Stage Deborah ${\rm Kent}^1$

¹*Hillsdale College.* 5:20 PM - 5:40 PM *Room 613/614*

The sensational news of Neptune's observation reached the United States about a month after the initial sighting at the Berlin observatory on 23 September 1846. The ensuing dispute over the priority of discovery captured both popular interest and scientific attention in America. A handful of ambitious scientists viewed the Neptune affair as an opportunity to establish the legitimacy of American science, especially in response to the perceived superiority of European science. This talk will focus on the role of Harvard mathematician Benjamin Peirce in questioning the mathematical particulars of the discovery and shaping related rhetoric to advance the professionalization of American science.

A Clear Yet Distant Echo: Modern-day Analogues of the Scientific Interest and Controversies Surrounding the Discovery of Neptune

Greg Laughlin¹, M. Brown² ¹UC Santa Cruz, ²Caltech. 5:40 PM - 6:00 PM Room 613/614

Our understanding of the solar system and the physical Universe has progressed almost immeasurably during the 164.79 years that constitute an orbit of Neptune. Nevertheless, the drama surrounding the discovery of Neptune still resonates with an immediacy that is both completely relevant and entirely up to date. In this talk, we will argue that the central themes surrounding Neptune's discovery (including issues of priority, improvements in observational and theoretical technique, and the nature of what constitutes an acceptably specific scientific prediction) all have readily evident analogues in the planethunting and solar system discovery efforts that are being carried out today. To support our arguments, we will make specific connections to (1) the ongoing effort to map and characterize the solar system's trans-Neptunian inventory, and (2) the search for extrasolar planets orbiting nearby stars.

Monday, January 10, 2011, 8:30 AM - 9:20 AM 101

Kavli Lecture: Cassini Eyes the Rings of Saturn Invited Session *Ballroom 6AB*

101.01 Cassini Eyes the Rings of Saturn Carolyn C. Porco¹

¹CICLOPS, Space Science Institute. Ballroom 6AB

For the past 6.5 years, NASA's Cassini spacecraft has been in orbit around the planet Saturn. In that time, Saturn has journeyed from the height of southern summer through early northern spring, allowing ample opportunity to observe changes in the planet's rings under a variety of lighting and viewing conditions. This presentation will highlight some of Cassini's most significant discoveries in this disk of icy rubble, emphasizing the connection between Saturn's rings and other astrophysical disk systems, such as protoplanetary disks and the giant spiral galaxies.

Monday, January 10, 2011, 9:00 AM - 6:30 PM 139 *NANOGrav Posters* Poster Session *Exhibit Hall*

139.01

Using Cyclic Spectroscopy of Pulsars to Correct for Interstellar Propagation Delay

Dan Stinebring¹, A. Spatzier¹, J. Nelson¹, S. Giri¹, C. Haddad¹, K. Kundert¹, M. Larkin¹, J. N. Nelson¹ ¹Oberlin College.

Exhibit Hall

Recently, Demorest et al. (2010) have demonstrated that, for pulsar observations, the phase of the e-m wave can be determined through a technique called cyclic spectroscopy. This is a major advance in high precision pulsar timing. We report on studies of how cyclic spectroscopy can be used to correct for interstellar propagation delays down to the 100 ns level. Substantial observing time on large telescopes will be necessary to put this important technique into practice.

139.02

Pulsar Phase Jitter and Cyclic Spectroscopy Derived Arrival Times

Nipuni Palliyaguru¹, M. McLaughlin¹, D. Stinebring²

¹West Virginia University, ²Oberlin College.

Exhibit Hall

In searching for gravitational waves with high-precision pulsar timing, we have analyzed the possibility of applying the method of cyclic spectroscopy (CS) to correct for the arrival time fluctuations of the signals. The main causes of these delays are interstellar medium effects such as electron density variations and multi-path scattering, timing noise, pulse shape changes, and pulse-to-pulse jitter. These phenomena affect the electromagnetic wave of the pulsar in both amplitude and phase. The CS method, developed recently by Demorest and collaborators (2010), takes into account the observed voltage signal of the pulsar in the frequency domain and computes a stable, integrable quantity. This quantity can, in principle, be used to determine the impulse response of the system, q(t). Determining q(t) at several observing frequencies should allow frequency dependent effects to be separated from achromatic effects. We have used simulated data assuming the observed signal to be a convolution of the intrinsic pulsar signal and q(t), with additive noise and phase jitter included. We can reconstruct the impulse response function from the simulated data and find an estimate of q(t). When done at several frequencies this allows an estimate for the true delay of the signal. We present the results of these simulations, focusing attention on the effects of pulse phase jitter.

139.03

Progress Towards a Pipeline for Continuous Gravitational Wave Searches in Pulsar Timing Data Justin Ellis¹, F. Jenet², M. McLaughlin¹

¹West Virginia University, ²University of Texas Brownsville. Exhibit Hall

Gravitational Waves (GWs) are tiny ripples in the fabric of space-time predicted by Einstein's General Relativity. Pulsar timing arrays (PTAs) are well poised to detect low frequency ($10^{-9} - 10^{-7}$ Hz) GWs in the near future. There has been a significant amount of research into the detection of a stochastic background of GWs from supermassive black hole binaries (SMBHBs). Recent work (Sesana et al 2010) has shown that single continuous sources standing out above the background may be detectable by PTAs operating at a sensitivity sufficient to detect the stochastic background. The main source of continuous GWs in the pulsar timing frequency band are extremely massive and/or nearby SMBHs. Here

we present progress towards a fully functional pipeline for continuous GW searches in pulsar timing data. This pipeline is based on a frequentist approach that relies on a matched filtering search of constructed template banks. We present methods for determining the optimal grid size in template space that maximizes the likelihood of detection and characterization of a given GW source. We also report progress on implementation of this pipeline into the TEMPO2 pulsar timing software package, in which the gravitational wave signal will be fit for in the pulsar timing residuals using a least squares fitting routine. This pipeline is versatile in that it can also be used for binary system parameter estimation and upper limit calculations on possible sources.

139.04

Optimizing a Pulsar Timing Array

Ryan Shannon¹, J. Cordes¹

¹Cornell Univ..

Exhibit Hall

Nanohertz gravitational radiation can be detected through the long term analysis of pulse arrival times from a set of millisecond pulsars (a pulsar timing array). The sources of this emission include inspiraling massive black hole binaries and cosmic strings.

Here, we assess the sensitivity of pulsar timing arrays to gravitational waves in the presence of a diverse range of noise sources both intrinsic and extrinsic to the pulsar.

Noise sources intrinsic to the pulsar include terms associated with pulsar rotational irregularities (timing noise) and jitter of the radio emission region. Extrinsic noise includes terms associated with reflex motion of the pulsar about unmodeled circumpulsar asteroid belts and propagation of the pulsar radio emission through turbulent plasma in the interstellar medium. We describe the amenability of these noise sources to various mitigation techniques, such as observing with higher sensitivity telescopes and multi-frequency time of arrival fitting.

We find that observations of more pulsars, observed with higher throughput (longer integrations times or faster observing cadences) are required to make a significant detection of gravitational radiation at cosmological levels and perform subsequent characterization of gravitational wave emitting sources. From this we conclude that pulsar timing is optimally conducted by using telescopes with a range of collecting areas, which can be achieved through coordinated global efforts utilizing current telescopes or a large array-based telescope.

139.05

Precision Millisecond Pulsar Timing: Space Velocities and Equivalence Principles

Ingrid H. Stairs¹, M. E. Gonzalez¹, R. D. Ferdman², P. C. C. Freire³, D. J. Nice⁴, P. B. Demorest⁵, S. M. Ransom⁵, R. N. Manchester⁶, G. B. Hobbs⁶, A. G. Lyne², M. Kramer³, F. Camilo⁷

¹Univ. of BC, Canada, ²University of Manchester, United Kingdom, ³MPIfR, Germany, ⁴Lafayette College, ⁵NRAO, ⁶CASS, Australia, ⁷Columbia University.

Exhibit Hall

We present high-precision timing results for 5 millisecond pulsars (MSPs), using data acquired with the Parkes and Arecibo telescopes. We measure the proper motion for each pulsar, infer 2-D space velocities, and update velocity distribution investigations of the MSP population, finding that binary and isolated MSPs have indistinguishable velocity distributions. We constrain binary inclination angles and hence masses for 2 of the pulsars in our sample. We use all the known wide-orbit pulsar--white-dwarf binaries to update previous limits on violation of the Strong Equivalence Principle and on a parameter describing violation of Lorentz invariance and momentum conservation.

139.06

High Precision Timing of Millisecond Pulsars at Arecibo and Green Bank

David J. Nice¹, P. B. Demorest², M. E. Gonzalez³, R. D. Ferdman⁴, S. M. Ransom², I. H. Stairs³, NANOGrav ¹Lafayette College, ²NRAO, ³UBC, Canada, ⁴University of Manchester, United Kingdom. *Exhibit Hall*

The NANOGrav consortium uses Arecibo and the GBT to make high-precision timing observations of twenty millisecond pulsars. All sources are observed at two frequencies using software coherent dedispersion systems. This program is motivated both by the search for a gravitational wave background and more traditional pulsar timing applications such as measuring binary orbits to test theories of gravitation and to measure neutron star masses. We will discuss the observing program and data analysis, and we will give highlights from the last five years of observations.

139.07

Characterizing the Radio Frequency Timing Stability of Fast and Millisecond Pulsars Isabel Mette Kloumann¹, J. M. Rankin¹

¹University of Vermont.

Exhibit Hall

We propose measuring the average profile stabilization rate in millisecond pulsars. We consider the correlations between a pulsar's global average profile and subaverage profiles constructed using increasing numbers of pulses, thereby quantifying the number of pulses required to build a stable average profile. We adopt the methodology developed by Helfand, Manchester, and Taylor (Ap. J., 1975) and later employed by Rathnasree & amp; Rankin (Ap. J., 1995) to calculate the stabilization rates of a sample of both fast and millisecond pulsars. A correlation coefficient is obtained by averaging the correlation coefficients of the global average profile with each subaverage profile of n pulses. By plotting how the correlation coefficient increases with n one can observe how the star's profile stabilizes as the number of pulses used to construct it increases. We look for values of n for which the correlation coefficient is statistically significant and interpret this value as the number of pulses required to compute a stable average profile of a given star. We expect n to be smaller for millisecond pulsars, as they typically exhibit very few intrinsic variations. This work considers the stars studied by Rathnasree & amp; Rankin, as well as millisecond pulsars that are of interest to the pulsar timing community and in particular the NANOGrav (North American Nanohertz Observatory for Gravitational Waves) initiative. The authors would like to acknowledge support from the US National Science Foundation.

139.08

ARCC@UWM: The Arecibo Remote Command Center at the University of Wisconsin--Milwaukee Xavier Siemens¹, C. Biwer¹, J. Clayton¹, J. Creighton¹, D. Day¹, D. Erb¹, K. Gustavson², F. Jenet³, D. Kaplan¹, R. Karr¹, M. Rohr¹, K. Stovall³

¹University of Wisconsin -- Milwaukee, ²Nicolet High School, ³University of Texas Brownsville. Exhibit Hall

A low frequency stochastic background of gravitational waves could be detected by pulsar timing experiments in the next five to ten years. Increasing the number of time of arrival data sets available for gravitational wave searches will improve the sensitivity of a pulsar based gravitational wave detector. To achieve this goal, a group of faculty, staff, postdoctoral researchers, and a graduate student at the University of Wisconsin--Milwaukee are participating in a broad effort to increase the number of known stable pulsars collecting and analyzing the pulsar Arecibo L-band Feed Array (P-ALFA) survey data, and the Green Bank Northern Celestial Cap survey data. We have followed the pioneering model started at the University of Texas-Brownsville (UTB) to involve undergraduate and high school students in this research. In close collaboration with the group at UTB we have engaged two local high school teachers,

several high school students, and about 15 UWM undergraduates in remotely commanding and observing using the Arecibo radio telescope and the Green Bank telescope, in searches in the collected data for new candidate pulsars, and follow-up observations of of potential pulsar candidates. In addition, the group is using its expertise in LIGO data analysis to improve gravitational wave searches in pulsar timing data.

140

Kepler Posters Poster Session Exhibit Hall

140.01

Kepler Target Pixel Files

Susan E. Thompson¹, S. McCauliff², S. Bryson², M. Still², J. van Cleve², J. Dotson², J. Twicken², T. Klaus², M. Cote², M. Fanelli²

¹SETI Institute/NASA Ames, ²NASA Ames Research Center.

Exhibit Hall

In early 2011, the Kepler Mission will make available the pixel data for all observed targets, in addition to the aperture photometry light curves currently provided at the Multi-mission Archive at STScI (MAST). These target pixel files will contain images of the calibrated flux, the subtracted background, and the removed cosmic rays for the target at each cadence. Certain targets, such as highly variable stars, non-stellar targets, or saturated targets, require an analysis beyond fixed, optimal aperture photometry in order to retrieve all the information from the data. For a few cases we demonstrate the utility of the target pixel files in understanding the quality of the data and in performing specialized aperture photometry. Kepler was selected as the 10th mission of the Discovery Program. Funding for this mission is provided by NASA, Science Mission Directorate.

140.02

The Kepler Guest Observer Program

Martin D. Still¹, M. Fanelli¹, K. Kinemuchi¹, Kepler Science Team

¹NASA Ames Research Center.

Exhibit Hall

Kepler is a NASA Discovery mission to identify and characterize Earth-size planets within the habitable zone around nearby stars. The Kepler instrument also provides an unprecedented opportunity to test and refine a diverse range of astrophysical paradigms with high-precision, uniform and rapid cadence data, containing none of the diurnal or seasonal gaps that limit ground-based observations. Kepler provides open opportunities to exploit existing data and propose for new targets and science. This poster provides directions to resources and data at the Kepler data archive at MAST and the Kepler Guest Observer Office.

140.03

Finding Planets from Variable Star Pulsation Arrival Times with Kepler

Fergal Mullally¹, K. Kinemuchi¹, S. E. Thompson¹, J. F. Rowe¹

¹*Kepler Science Office.*

Exhibit Hall

We examine the potential for planet detection using lightcurve arrival times around a variety of stars in the Kepler field. Arrival time analysis has been used to find planets around pulsars and sub-dwarf stars. When a variable star is orbiting the center of mass of a planetary system, its distance from the earth changes periodically. This change in distance is observed as a change in the observed arrival time of

otherwise stable pulsations here on Earth. The sensitivity of the technique is set by the jitter of the pulsation period and phase, and the periods of detectable planets by the long term stability of the pulsation modes. We examine the limits that can be placed of a variety of variable stars using public data from the first quarter of observations by the Kepler space telescope.

Kepler was selected as the 10th mission of the Discovery Program. Funding for this mission is provided by NASA, Science Mission Directorate

140.04

An Update to the Kepler Eclipsing Binary Catalog: the use of Pixel Time Series to Identify Blended Eclipsing Binary Systems

Michael Rucker¹, N. M. Batalha¹, A. Prsa², S. T. Bryson³, L. R. Doyle⁴, R. W. Slawson⁴, W. F. Welsh⁵, J. A. Orosz⁵

¹Department of Physics and Astronomy, San Jose State University, ²Department of Astronomy and Astrophysics, Villanova University, ³NASA Ames Research Center, ⁴SETI Institute, ⁵Astronomy Department, San Diego State University.

Exhibit Hall

The Kepler telescope is providing a nearly seamless stream of photometric data of approximately 150,000 stars with unprecedented precision. The Kepler Eclipsing Binary (EB) catalog (based on the first 43 days of data; arXiv:1006.2815) is being continuously augmented as more data are collected and EBs are detected at longer periods. The catalog is expected to contain a small fraction of blends - cases where the eclipse signature is from a nearby source in the photometric aperture. In constructing the original catalog, obvious blends were identified and removed and/or reassigned to the appropriate point source. We build upon this work by performing pixel-level tests similar to those used to identify false positives amongst the Kepler exoplanet candidates. We summarize these tests here and provide examples that illustrate the types of blend scenarios that we have identified. Where appropriate and possible, we modified Kepler's target list with the newly found Kepler star identification numbers. The changes reported here will affect the target lists which will go into effect on December 23, 2010 (start of Quarter 8). An updated version of the Kepler Eclipsing Binary catalog is available online at NASA's Multimission Archive at STSci (MAST) website (http://archive.stsci.edu/kepler).

140.05

Pixel-Level Analysis Techniques for False-Positive Identification in Kepler Data

Steve Bryson¹, J. Jenkins², R. Gilliland³, N. Batalha⁴, T. N. Gautier⁵, J. Rowe¹, E. Dunham⁶, D. Latham⁷, D. Caldwell², J. Twicken², P. Tenenbaum², B. Clarke², J. Li², H. Wu², E. Quintana², D. Ciardi⁵, G. Torres⁷, J. Dotson¹, M. Still¹

¹NASA Ames Research Center, ²SETI/NASA Ames Research Center, ³Space Telescope Science Institute, ⁴SJSU/NASA Ames Research Center, ⁵Jet Propulsion Laboratory, ⁶Lowell Observatory, ⁷Harvard-Smithsonian Center for Astrophysics.

Exhibit Hall

The Kepler mission seeks to identify Earth-size exoplanets by detecting transits of their parent star. The resulting transit signature will be small (~100 ppm). Several astrophysical phenomena can mimic an Earth-size transit signature, most notably background eclipsing binaries (BGEBs). As part of a larger false-positive identification effort, pixel-level analysis of the Kepler data has proven crucial in identifying the likelihood of these confounding signals. Pixel-level analysis is primarily useful for the case of the transit being a BGEB. Several analysis techniques are presented, including:

- measurement of centroid motion in and out of transit compared with detailed modeling of expected centroid motion, including an estimate of the transit source location

- transit source location determination through a high-precision PSF-fit of the difference between in-

and out-of-transit pixels, directly measuring the location of the transit source

- source location determination through fitting the observed summed flux time series (or the light curve derived from the transit model) to each pixel's time series data.

These techniques have been automated and are being considered for inclusion in the Kepler Science Operations Center Data Analysis Pipeline. They are supplemented by various diagnostic plots of the Kepler data as well as comparison with background stars identified by the Kepler Follow-up Observing Program (FOP). The final determination of whether an observed transit is a false positive integrates several sources, including pixel-level analysis and FOP results. Pixel-level techniques can identify BGEBs that are separated from the Kepler target star by more than a certain radius, called the "radius of confusion". The determination of the radius of confusion, and the role it plays in assigning the probability of the transit being due to a planet, is briefly discussed. The statistics from the latest falsepositive list are provided.

Funding for this mission provided by NASA's Discovery Program Office, SMD.

140.06

The Kepler Data Archive at MAST: What's in it for me?

Dorothy A. Fraquelli¹, R. Thompson¹, S. Tseng¹, M. Smith¹

¹Computer Sciences Corp..

Exhibit Hall

Hosted by MAST, the Multi-Mission Archive at Space Telescope, the Kepler Archive now contains over a year's worth of observations on more than 150,000 objects. The observations consist of light curves, both public and proprietary, target pixel files and full frame images (FFI). Supporting information includes data release notes, the Instrument Handbook, an Archive Manual and SPIE papers describing the instrument and data processing (in advance of the Kepler Data Hand Book). High level science products (HLSP) for the announced planets are available. The archive also contains the Kepler Input Catalog (KIC), the Kepler Target Catalog (KTC) and the Characteristics Table (CT).

We will show examples of how to search for and retrieve data, including FFIs and light curves, how Kepler GOs and science team members can download their data from an ftp area, how to view public light curves and FFIs, and, for Kepler proposers, how to locate objects in the KIC. We will discuss the different ways of retrieving Kepler data. A companion poster details MAST's GALEX-Kepler cross-match catalog, a unique product that supplies UV colors to complement the KIC's ground-based observations. Demos of the web site are available at the STScI booth.

140.07

Public Kepler Data on the Bright Star Theta Cygni

Michael Robert Haas¹, S. T. Bryson¹, J. F. Rowe¹, M. D. Still²

¹NASA Ames Research Center, ²BAER Institute.

Exhibit Hall

The bright star Theta Cygni (Kepler ID 11918630) has been observed by Kepler in both short (59 sec) and long (29.4 min) cadence for a period of approximately 50 days starting on MJD 55410. These observations were made at the request of the Kepler Guest Observer Office and are intended for immediate public release. The purpose is to demonstrate Kepler's exquisite photometric precision on bright, highly saturated targets. Theta Cygni is a F3V/M3V binary with a visual magnitude of 4.9/13.0. The short-cadence data show evidence of granulation (i.e., convection) out to about 1 mHz (~100 c/d) and clear detection of numerous p-modes with a peak near 1.8 mHz (~150 c/d). The high-frequency noise floor has a 3-sigma upper envelope of 0.4 ppm. The amplitude of the p-modes agrees with the stellar effective temperature, indicating that the star has a thin convective layer. Since a custom aperture was employed, the light curves will be constructed manually and placed on the Guest Observer

website (http://keplergo.arc.nasa.gov/). The corresponding pixel-level data will be available from the Kepler archive (http://archive.stsci.edu/kepler/). The Kepler mission can accommodate a small number of such bright targets every quarter. Observing proposals can be submitted annually to the peer-reviewed Guest Observer Program, or much less formally on a quarterly basis for Director's Discretionary Time (see http://keplergo.arc.nasa.gov/GOprogramDDT.shtml). Kepler was selected as the 10th mission of the Discovery Program. Funding for this mission is provided by NASA, Science Mission Directorate.

140.08

Application of Bayesian Systematic Error Correction to Kepler Photometry

Jeffrey E. Van Cleve¹, J. M. Jenkins¹, J. D. Twicken¹, J. C. Smith¹, M. N. Fanelli² ¹SETI Institute/NASA Ames Research Center,, ²Bay Area Environmental Research Institute. Exhibit Hall

In a companion talk (Jenkins et al.), we present a Bayesian Maximum A Posteriori (MAP) approach to systematic error removal in Kepler photometric data, in which a subset of intrinsically quiet and highly correlated stars is used to establish the range of "reasonable" robust fit parameters, and hence mitigate the loss of astrophysical signal and noise injection on transit time scales (<3d), which afflict Least Squares (LS) fitting. In this poster, we illustrate the concept in detail by applying MAP to publicly available Kepler data, and give an overview of its application to all Kepler data collected through June 2010. We define the correlation function between normalized, mean-removed light curves and select a subset of highly correlated stars. This ensemble of light curves can then be combined with ancillary engineering data and image motion polynomials to form a design matrix from which the principal components are extracted by reduced-rank SVD decomposition. MAP is then represented in the resulting orthonormal basis, and applied to the set of all light curves. We show that the correlation matrix after treatment is diagonal, and present diagnostics such as correlation coefficient histograms, singular value spectra, and principal component plots. We then show the benefits of MAP applied to variable stars with RR Lyrae, harmonic, chaotic, and eclipsing binary waveforms, and examine the impact of MAP on transit waveforms and detectability. After high-pass filtering the MAP output, we show that MAP does not increase noise on transit time scales, compared to LS. We conclude with a discussion of current work selecting input vectors for the design matrix, representing and numerically solving MAP for non-Gaussian probability distribution functions (PDFs), and suppressing high-frequency noise injection with Lagrange multipliers. Funding for this mission is provided by NASA, Science Mission Directorate.

140.09

Validation of Candidate Multiple-Transiting Planet Systems and Assessing Possible False Positives based on Photometric Observables

Robert Morehead¹, E. B. Ford¹, Kepler Science Team

¹University of Florida.

Exhibit Hall

Planetary systems with multiple planets that transit their host star are of great interest for studying the architecture of planetary systems (Steffen et al. 2010; Holman et al. 2010). Even space-based exoplanet transit surveys, such as CoRoT and *Kepler*, must be careful to exclude astrophysical false positives that can mimic the photometric signature of multiple-transiting planet system (MTPS). Due to large point spread functions, a putative MTPS might actually be: 1) a true MTPS, 2) a blend of an eclipsing binary and a star with a single transiting planet, 3) a blend of two eclipsing binaries, or 4) two stars each with a single transiting planet. Assessing the relative probability for each of these possibilities is important both for validating potential planets and for prioritizing the limited follow-up resources that can contribute to validation or confirmation of such systems.

We introduce new observable parameters based on ratios of the measured transit durations in MTPSs, as well as the measured orbital periods and (when available) impact parameters. We explore the utility of these parameters for validating candidate MTPSs and/or rejecting false positives. For multiple planets around the same star, these parameters have values near one. The distribution of these parameters for certain blend scenarios can be markedly different. We investigate these distributions through Monte Carlo simulations of three different types of blends; planet-binary, binary-binary, and planet-planet and compare these to the distribution for true MTPSs. We present results based on previously released *Kepler* data and simulations using multiple distributions for the orbital inclinations, eccentricities, and binary star population.

Kepler was selected as the 10th mission of the Discovery Program. Funding for this mission is provided by NASA, Science Mission Directorate

140.10

Kepler Eclipsing Binary Stars: on the Origin of Contact Binaries and the Degree of Thermal Contact Andrej Prsa¹, E. F. Guinan¹, S. Rucinski², B. Kirk¹, C. Villamil¹

¹*Villanova University,* ²*University of Toronto, Canada.*

Exhibit Hall

Contact binary stars (W UMa-type binaries) are one of most ubiquitous close binaries in our Galaxy. The components evolved into a system that shares a common envelope and features active mass transfer. Because of the components' proximity, orbital periods of these systems are short (2-18 hours) and the orbital velocities are large (100-300 km/s). It might be expected that contact binary envelopes are in thermal contact, yet the observations indicate otherwise. Further, the evolution of these stars is speculated to be due to either tidal/magnetic tightening of the orbit or to 3rd body interaction, yet to date there is no definitive consensus. Kepler holds great promise in resolving these puzzles since the ultra-high precision photometry allows us to model the target stars to unprecedented accuracy. In September 2010 we acquired high-resolution echelle spectra at the 4-m Mayall telescope (Kitt Peak, AZ) of 15 select contact binaries in the Kepler field at 5 phases distributed uniformly across the phase space. These observations provided us with the masses, projected semi-major axes, and center-of-mass radial velocities of program stars, and allowed us, in conjunction with the Kepler data, to completely characterize the absolute properties (masses, radii, temperatures, luminosities) of these prime W UMatype binaries. Here we present a preliminary analysis of three select systems, KepIDs 8496820, 9392682, and 12305537, based on the public Kepler data and high-resolution spectroscopy. The final analysis of these and other stars will be supplemented with the proprietary Kepler data obtained through the Cycle II Guest Observer program 09-KEPLER09-0054, which we gratefully acknowledge. This work was funded in part by NSF/RUI grant AST-05-07542.

140.11

A Spectral and Lightcurve Study of 50+ Blue Stars from the Burrell-Optical-Kepler-Survey (BOKS) Jared Lalmansingh¹, S. Howell², D. Walter¹, J. Cash¹, K. Mighell²

¹South Carolina State University, ²National Optical Astronomy Observatory. Exhibit Hall

BOKS used the 0.6 m Burrell-Schmidt telescope over a period of 40 nights and identified 54,687 stars between 14 < r < 19 in the Kepler Mission's field of view. Its primary goal was to detect Jupiter-sized and Hot Jupiter (Period = 3 - 9 days) short-period exoplanets within the survey field as well as to compile high precision stellar variability data that the Kepler Mission can use for comparison purposes and to characterize the hundreds of other variable stars within the survey region.

We present the spectral classifications and light curve analysis of a sub-sample of 50+ blue stars within the BOKS field of view using BOKS lightcurve data and spectra from the Kitt Peak 2.1 meter telescope.

The purpose of this study is to identify the variability of and provide characterization for the blue star population within the BOKS field.

Support for this work was provided by NOAO and the NSF PAARE program to South Carolina State University under award AST-0750814.

140.12

A Method for Determining Precise Phase Shifts of Eclipses in EB Systems: Detecting Substellar, Non-Transiting Third Bodies in Kepler Mission Eclipsing Binary Light Curves.

Robert W. Slawson¹, L. R. Doyle¹

¹SETI Institute.

Exhibit Hall

A third body orbiting an eclipsing binary induces a small phase shift in the eclipses due to the light time effect as the binary system orbits about the three-body barycenter. The presence of the small third-body is revealed by a periodicity in the phase shifts consistent with a Keplerian orbit.

We present a cross-correlation method that benefits from the nearly continuously sampled light curves now becoming available from the Kepler mission. For the template, we use a model light curve of the binary system that is stationary in phase (dP/dt=0, d ω /dt=0, ...). A window function slides in time along both the observed light curve and template selecting a region for cross-correlation and the phase shift as a function of time is determined from the peak in the resulting correlation function.

We examine the sensitivity limits, through numerical experiments, to the detection of substellar and planet sized masses in multi-year orbits about EBs from Kepler mission light curves.

140.13

Kepler Systems That Show Multiple Transiting Objects

Jason H. Steffen¹, D. C. Fabrycky², E. B. Ford³, M. J. Holman⁴, J. J. Lissauer⁵, D. Ragozzine⁴, W. F. Welsh⁶, Kepler Science Team

¹Fermilab, ²UC Santa Cruz, ³University of Florida, ⁴Harvard CfA, ⁵NASA Ames, ⁶San Diego State University. Exhibit Hall

Exoplanetary systems that have multiple transiting planets provide unique and important insight into the formation, evolution, and dynamics of exoplanetary systems. Kepler has announced the discovery of a confirmed planetary system with multiple transiting planets (Kepler 9, Holman et al. 2010) as well as several candidate planetary systems that show multiple transiting objects (Steffen et al. 2010). Kepler 9 shows deviations from a constant period due to the ongoing dynamical interactions between the confirmed planets. From these transit timing variations (TTV) one can measure the planetary masses from the photometric data alone. The presence of several systems with multiple transiting candidates from the first quarter of data indicate that Kepler should continue to find systems with multiple transiting planets. Such systems will provide important, general information about the histories of planetary systems.

140.14

The Faring Behavior of G and K Dwarfs as Seen in the Kepler Q1 Data

Peiyuan Mao¹, D. Soderblom², R. Osten², J. Valenti²

¹Lafayette College, ²Space Telescope Science Institute.

Exhibit Hall

The white-light photometric observations from the Kepler mission are the first ever look at the behavior of solar-type stars at ultra-high precision, and the light curves made available in the "Q1" data release show many astrophysical phenomena. Especially evident in a small fraction of the G and K dwarfs are flaring events, with rapid rises and exponential decays. These flares have much greater energies and longer decay time-scales than even the largest solar flares, which would be undetectable given Kepler's

30-minute observing cadence. Moreover, stars that exhibit flares tend to show several flares during the 33.5 day interval covered by the Q1 data. Aside from the Kepler data itself, little is known about these stars and what sets them apart from other Kepler targets with similar rotation periods and variability amplitudes. We will show examples of flares in the Kepler light curves, describe our detection technique, and present our initial findings on this phenomenon.

140.15

Parameterizing and Modeling Eclipsing Binaries in The Kepler Field Using Kepler Quarter 2 and 3 Data Sean Morrison¹, K. Mighell², S. Howell², D. Bradstreet³

¹Appalachian State University, ²National Optical Astronomy Observatory, ³Eastern University. Exhibit Hall

We present a preliminary analysis of Quarter 2 and Quarter 3 Kepler light curves for 56 eclipsing binary star systems from the Kepler Cycle 1 program 08-KEPLER08-0014, "A Calibration Study of Variable Stars in the Kepler Field" (PI: Mighell). We developed a C program to phase these long cadence (30 minute) data that determines the period and zero point with a typical precision of 0.0864 seconds for an orbital period of 1.019949 days. We have developed 3D models of the systems using Binary Maker 3 (BM3) by David Bradstreet. Spectra of 32 of the systems were obtained at the Kitt Peak National Observatory 2.1 m telescope using the GoldCam spectrometer. We have determined temperatures for some of the stars from the temperature ratios, based on the BM3 models, and the average temperatures for the spectral classifications of the stars which were derived from the 2.1-m spectra. The high photometric precision of the Kepler light curves allows us to identify significant star spots on a subset of the systems. Morrison was supported by the NOAO/KPNO Research Experiences for Undergraduates (REU) Program and the Department of Defense ASSURE program through Scientific Program Order No. 13 (AST-0754223) of the Cooperative Agreement No. AST-0132798 between the Association of Universities for Research in Astronomy (AURA) and the NSF.

140.16

Cross Matching of Available GALEX Objects with Kepler Targets at MAST

Myron Smith¹, B. Shiao², Kepler

¹Computer Sciences Corp., ²Space Telescope Science Institute. Exhibit Hall

The recent release of the GALEX Release 6 dataset includes 72 sky "tiles" overlapping some 60% of the Kepler Field of View. MAST (Multi-Mission Archive at Space Telescope Science Institute) has constructed a cross-match catalog of all matches of GALEX objects with 5" of the coordinates for objects in the Kepler Input Catalog (KIC) and vice-versa.

The results permit the addition of UV colors (near-UV and/or far-UV, centered at about 2300 Angstroms and 1500 Angstroms, respectively) to

the SDSS program's *griz* filters that the Kepler ground-based support photometric program emulated. Until now the absence of an ultraviolet filter for this ground survey of KIC objects has meant that it was not possible to clearly identify hot (OBA-type) objects. The addition of the GALEX UV magnitudes will address this deficiency. In addition, the (FUV-NUV) vectors for ISM reddening and stellar temperature are very different, allowing the former degeneracy of the two terms to be lifted. We exhibit on-line tools to enable users to obtain UV, *griz*, and 2MASS colors to aid in the search of targets and to investigate general distributions of objects in the KIC. We discuss completeness of the cross-match survey with the KIC catalog. We point out that the numbers of detections are primarily limited by the far-UV and near-UV effective apertures of GALEX.

140.17 Kepler Light Curves of AGN Michael T. Carini¹, W. Welsh²

¹Western Kentucky University, ²San Diego State University.

Exhibit Hall

The Kepler mission is observing the same region of the sky for its entire mission lifetime, allowing virtually uninterrupted optical observations of any object in its field of view. This provides the opportunity to obtain optical light curves of AGN of unprecedented duration and sampling. During cycle 1, we obtained observations of two bright AGN in the Kepler field of view: the Seyfert 1 galaxy ZW 229.015 and the Seyfert 2 galaxy IGR J19473+4452. We present the light curves of these sources and discuss their variability properties. Because the Kepler Pipeline is optimized for detecting transiting planets, not photometry of extended sources, we also discuss potential systematic problems and cautions one must have when interpreting these light curves.

140.18

Mining the Kepler Mission Database: Rotations, Starspots, Ages and Possible Tidal Interactions of Stars with Close-in Planets

Greg Feiden¹, E. Guinan², T. Boyajian³, Y. Kok⁴, O. Basturk⁵, A. Roberson⁶, I. Ribas⁷

¹Dartmouth College, ²Villanova University, ³Georgia State University, ⁴University of Sydney, Australia, ⁵Ankara University, Turkey, ⁶Pennsylvania State University, ⁷Institut de Ciencies de l'Espai, Spain. Exhibit Hall

The first public data release from the Kepler Space Telescope contained over 156,000 stars which had been monitored continuously for approximately 33 days. With continuous photometric monitoring and unprecedented ultra-high precision, the Kepler dataset is an splendid resource for investigating stellar rotation (and age) via starspots as well as for investigating starspot fractional coverage and distributions, starspot lifetime and differential rotation as a function of spectral type and rotation/age. Here, we narrowed our focus to the ~306 planetary candidates, mostly main sequence late F, G and K stars, released during June 2010 (see Boruki et al. 2010). This is an attractive data set for the study of starspots properties since these stars host transiting planets with orbital planes almost exactly aligned with our line-of-sight and will generally have the host stars' rotation axes perpendicular to the planetary orbital plane. Thus, the inclination of the star's rotation axis can be assumed known and should (in most cases) be at right angles to our line-of-sight. Using a Lomb-Scargle Periodogram analysis, we have extracted reliable rotation periods and spot coverages for stars which showed evidence for starspots. From the measured rotation periods, we were able to determine, empirically, the age of the stellar system (using Villanova rotation-age relations) and investigate the potential tidal evolution of the planet-star system. However, we found good evidence that rotation-age relations do not apply to stars that host shortperiod, Jupiter sized planets. The aforementioned stars show a definite tendency towards star-rotationplanet orbital synchronization. The initial results of this exploratory program will be discussed. This project was initiated at the 2010 Sagan Exoplanet Summer Workshop hosted by NExScI at Caltech. We wish to thank NASA and the organizers of the workshop - in particular Dawn Gelino and Carolyn Brinkworth. EG wishes also to acknowledge support from NSF/RUI Grant AST-10-09903.

140.19

Piecing Together Planet Populations: How RV Super-Earth Frequency Predictions Measure up to Kepler's Planet Candidates

Angie Wolfgang¹, G. Laughlin¹

¹University of California, Santa Cruz.

Exhibit Hall

Based on the mass and period distributions of the super-Earths discovered by the Geneva Extrasolar Planet Search, there are expected to be planets less massive than Neptune orbiting a large fraction of main sequence stars in periods of 50 days or less. Expanding on this prediction, we employ a Monte Carlo method to create populations of super-Earths with varying compositions, mass distributions, and period distributions. We then compare the results of these simulations with the planet candidates announced by Kepler on June 15, 2010, calculating a statistical best fit to identify the radial velocity super-Earth population which is most likely to reproduce Kepler's population of planet candidates.

140.20

Kepler Measurements of M Star Variability

Geoffrey Bryden¹, J. Stauffer², D. R. Ciardi³, NStED Science Team

¹JPL, ²Caltech, ³NExScl.

Exhibit Hall

Late-type stars may be ideal candidates for detection of Earth-mass planets - lower stellar mass corresponds to larger radial-velocity amplitude and deeper transit depth for a given planet mass/size. Low-mass stars are only good targets, however, if they can be observed at noise levels similar to those for solar-type stars. As an exploration of the inherent variability of low-mass stars, we have identified a sample of 63 nearby M dwarfs within the Kepler field of view. The Kepler lightcurves for these stars generally vary by ~1% over the 33-day observational window. After subtraction of gradual long-term trends, only a handful of the stars exhibit variability above the photon-noise limit (typically 0.1-1.0 mmag). We conclude that >90% of M dwarfs are quiet within the several hour timeframe appropriate for detection of planetary transits.

140.21

Confirming sub-Neptunian Transiting Exoplanets with Kepler

Natalie M. Batalha¹, Kepler Science Team

¹San Jose State University.

Exhibit Hall

NASA's Kepler Mission, launched in March 2009, uses transit photometry to detect and characterize exoplanets with the objective of determining the frequency of earth-size planets in the habitable zone. The instrument is a wide field-of-view (115 square degrees) photometer comprised of a 0.95-meter effective aperture Schmidt telescope feeding an array of 42 CCDs that continuously and simultaneously monitors the brightness of up to 170,000 stars. In January, 2010, the team announced its first 5 planet discoveries identified in the first 43 days of data and confirmed by radial velocity follow-up. The "first five" are all short-period giant planets, the smallest being comparable in size to Neptune. Collectively, they are similar to the sample of transiting exoplanets that have been identified to date, the roster of which currently hovers around 100. In August 2010, an additional two planets, each orbiting the star Kepler-9, were confirmed by a combination of radial velocity and transit timing measurements. A third, smaller planet in the same system was validated stastistically by probing the parameter space for potential false-positives. Throughout 2010, a concerted effort was made to push radial velocity confirmation down toward the smaller planets. Recent progress on our efforts to confirm such candidates is discussed.

141 *Gamma Ray Bursts* Poster Session *Exhibit Hall*

141.01

High Metallicity LGRB Hosts

John Graham¹, A. Fruchter², E. Levesque³, L. Kewley³, J. Brinchmann⁴, S. Charlot⁵, A. Levan⁶, N. Tanvir⁷, S. Patel⁸, K. Misra², K. Huang⁹, D. Reichart¹⁰, M. Nysewander²

¹STScI & JHU, ²STScI, ³IFA, ⁴Leiden, Netherlands, ⁵Bordeaux, France, ⁶Warwick, United Kingdom, ⁷Leicester, United Kingdom, ⁸National Space Science & Technology Center, ⁹JHU, ¹⁰UNC. Exhibit Hall

One of the most powerful means to study the formation and evolution of gamma-ray bursts is by observing there environments. While short bursts have been detected in nearby galaxies of all types, long burst hosts are dominated by blue irregulars leading to speculation of metal poor host galaxies, a result which has now been confirmed via emission line metallicity diagnostics. However beginning with LGRB 051022 at log(O/H)+12 = 8.77 (using the R23 method with Kobulnicky & amp; Kewley 2004 scale) three exceptions to this trend have been found. This extends the metallicity range of LGRB hosts to that found throughout the Milky Way, challenges conventional wisdom that LGRBs require low metallicity progenitor environments and has significant implications in understanding LGRB formation. Here I present the results of our observations of two of these super-solar metallicity host galaxies, analysis of the high Z host population with respect to various comparison samples, and ongoing efforts to more directly probe the metallicities of the burst progenitors.

141.02

The Stellar Ages and Masses of Short GRB Host Galaxies: Investigating the Progenitor Delay Time Distribution and the Role of Mass and Star Formation in the Short GRB Rate

Camille N. Leibler¹, E. Berger¹

¹Harvard University.

Exhibit Hall

We present multi-band optical and near-infrared observations of 19 short y-ray burst (GRB) host galaxies, aimed at measuring their stellar masses and population ages. The goals of this study are to evaluate whether short GRBs track the stellar mass distribution of galaxies, to investigate the progenitor delay time distribution, and to explore any connection between long and short GRB progenitors. Comparing the distribution of stellar masses found using a single-stellar population model to the general galaxy mass function, we find that short GRBs track the cosmic stellar mass distribution only if the latetype hosts generally have maximal masses. However, there is an apparent dearth of early-type short GRB hosts compared to the equal contribution of early- and late-type galaxies to the cosmic stellar mass budget. These results suggest that stellar mass may not be the sole parameter controlling the short GRB rate, and raise the possibility of a two-component model with both mass and star formation playing a role (reminiscent of the case for Type Ia supernovae). If short GRBs in late-type galaxies indeed track star formation activity, the resulting typical delay time is ~ 0.2 Gyr, while those in early-type hosts have a typical delay of \sim 3 Gyr. Using the same stellar population models to fit 22 long GRB host galaxies in a similar redshift range we find that they have significantly lower masses and younger population ages. Most importantly, the two GRB host populations remain distinct even if we consider only the starforming hosts of short GRBs, supporting our previous findings (based on star formation rates and metallicities) that the progenitors of long GRBs and short GRBs in late-type galaxies are distinct.

This work was partially supported by Swift AO5 grant #5080010 and AO6 grant #6090612. Additional support was provided by the Harvard College Research Program.

141.03

A Beaming-Independent Estimate of the Distribution of Gamma Ray Burst Energies

Isaac S. Shivvers¹, E. Berger¹ ¹Harvard University. Exhibit Hall AAS 217 Winter Meeting Abstract Submission Isaac Shivvers and Dr. Edo Berger Harvard University

A Beaming-Independent Estimate of the Distribution of Gamma Ray Burst Energies

The single most important parameter of any cosmological explosion is the energy release. Energy measurements provide insight into the progenitor object and the explosion mechanism. The measurement of gamma-ray burst (GRB) energies has, traditionally, been a complicated problem due to highly non-spherical energy distributions and relativistic beaming effects. However, on timescales of >100 days GRBs become roughly non-relativistic and spherical. Using radio observations from the Very Large Array at times >100 days after the burst, we are able to calculate the energies of 20 bursts free from the large corrections needed when using early-time observations. We find a median energy in good agreement with results calculated through detailed analysis of multi-wavelength light curves. The similarity between methods provides further evidence that the bulk of the energy budget of GRBs is in the relativistic outflow and not in slower, lagging material. Our results were achieved economically, with only a few radio-wavelength flux measurements per GRB. We suggest that similar future observations with the Expanded VLA will provide unique insight into GRB energetics.

141.04

Quantifying GRB Pulse Shape Evolution to Study the Pulse Scale Conjecture

Daniel Miller¹, R. J. Nemiroff¹, J. Holmes¹, A. Shahmoradi¹

¹*Michigan Technology University.*

Exhibit Hall

The asymmetry of isolated gamma ray burst pulses is quantified by a simple ratio of rising to decaying fluence. This ratio can be defined in a background independent way by using only the peak of the pulse. This ratio is used to explore the prevalence of the Pulse Scale Conjecture (PSC; Nemiroff 2000) for a series of the brightest isolated BATSE GRB pulses known. The PSC posits that the shape of a GRB pulse is invariant across energy channels, scaling only in time and brightness. Within statistical uncertainties, it is found that some GRB pulses hold well to the PSC, whereas others do not. Moreover, for some GRB pulses, the PSC appears to hold only between specific energy channels. Examples will be shown and discussed.

141.05

Evidence for a Correlation Between Gamma-Ray Burst Variability and the Optical Afterglow Onset Sarah Yost¹

¹St John's Univ..

Exhibit Hall

The intrinsic variability (V) of prompt gamma-ray emission from gamma-ray burst (GRB) events is compared to the properties of the subsequent afterglow onset, yielding evidence of a correlation between V and the the optical onset's peak. We used Liang et al.'s (2009) fitted properties of the optical

onset bump in 16 events with an observed optical rise and known redshift, and calculated V from the lightcurves in the Swift gamma-ray data archive. The optical onset properties are known to be mutually correlated; comparing these optical bump properties to V shows positive correlations at the 3-sigma level with (de-redshifted) width, peak time, rise, and decay times and negative correlations with peak flux and the ratio of rise to decay times. When the bump peak time or width are expressed as a ratio of the GRB duration (T90), the correlation evidence with V is weaker.

141.06

Pulse Scaling Properties of Gamma-Ray Bursts

Justin Holmes¹, R. J. Nemiroff¹, D. Miller¹

¹Michigan Technological University. Exhibit Hall

Gamma-ray bursts (GRBs) hold potential as standard candles for the high redshift universe. To help identify relationships which may arise in GRBs that could lead to a standard candle, isolated pulses from a number of very bright GRBs were inspected regarding their pulse scaling nature. A direct test of the pulse scale conjecture was conducted using energy channel data from the Burst and Transient Source Experiment (BATSE). The test consisted of taking a light curve for a bright GRB pulse from a specific BATSE energy channel, scaling it in brightness and time, and finding the best statistical fit for the same GRB pulse in a different BATSE energy channel. Many of the GRB pulses tested showed a statistically acceptable scaling between at least two BATSE energy channels.

141.07

Search for Late Jet Breaks in X-ray Afterglows of Gamma-Ray Bursts

David N. Burrows¹, J. Racusin²

¹Penn State Univ., ²NASA/GSFC.

Exhibit Hall

Gamma-ray bursts are the most energetic events known since the Big Bang. Because both the prompt emission and the afterglow of GRBs is highly beamed, determination of their actual explosion energies depends on measurement of the beaming angle, which can be estimated on the basis of the detection of an achromatic jet break in the light curve. Jet break measurements for Swift GRBs have been rare; as a result, we have undertaken a program of studying X-ray GRB afterglows using the Chandra observatory to obtain very late-time flux measurements. When compared with earlier Swift XRT flux measurements, these allow the measurements of late jet breaks in some bursts, and allow strict limits to be placed on jet break times in other cases. We will present a progress report on this work and its implication for GRB energetics. 142 AGN, QSO, Blazars **Poster Session** Exhibit Hall

142.01

15 GHz Radio Variability of Gamma-Ray Blazars

Joseph Richards¹, W. Max-Moerbeck¹, V. Pavlidou¹, T. J. Pearson¹, A. C. S. Readhead¹, M. A. Stevenson¹, O. G. King¹, R. Reeves¹, E. Angelakis², L. Fuhrmann², J. A. Zensus², S. E. Healey³, R. W. Romani³, M. S. Shaw³, K. Grainge⁴, G. B. Taylor⁵, G. Cotter⁶

¹California Institute of Technology, ²Max-Planck-Institut-für-Radioastronomie, Germany, ³Stanford University, ⁴University of Cambridge, United Kingdom, ⁵University of New Mexico, ⁶University of Oxford, United Kingdom.

Exhibit Hall

Since 2007, the Owens Valley Radio Observatory (OVRO) 40 meter telescope has been engaged in an intensive fast-cadence gamma-ray blazar monitoring program, observing about 1500 objects twice per week. Using our intrinsic modulation index method and careful likelihood analyses, we find that gammaray loud objects associated with Fermi 1LAC sources in our sample demonstrate radio variability amplitudes significantly larger than do gamma-ray quiet objects. We also find significant differences in variability amplitude between flat spectrum radio guasars and BL Lacertae objects within our sample as well as possible evidence for cosmological evolution of variability amplitude.

142.02

Physical Significance Of The Time Lags In Radio/gamma-ray Cross-correlations For Fermi-gst Blazars On The Ovro 40m Blazar Monitoring Program

Walter Max-Moerbeck¹, J. L. Richards¹, V. Pavlidou¹, T. J. Pearson¹, A. C. S. Readhead¹, M. A. Stevenson¹, O. King¹, R. Reeves¹, E. Angelakis², L. Fuhrmann², J. A. Zensus², S. E. Healey³, R. W. Romani³, M. S. Shaw³, K. Gainge⁴, G. B. Taylor⁵, G. Cotter⁶

¹California Institute of Technology, ²Max-Planck-Institut für Radioastronomie, Germany, ³Stanford University, ⁴University of Cambridge, United Kingdom, ⁵University of New Mexico, ⁶University of Oxford, United Kingdom.

Exhibit Hall

The OVRO 40 m telescope has been monitoring ~1500 blazars since 2007. The sources are observed twice per week at 15 GHz. The sample contains all CGRaBS sources and the gamma-ray blazars detected by Fermi which are visible from OVRO. The availability of a large sample of sources with good cadence at radio and gamma-ray offers the opportunity to test the suggestion of correlated variability between these two bands. A Monte Carlo method to assess the physical significance of the cross-correlations taking into account the properties of the light curves and the uneven sampling is presented. Application to an early data set shows that in most cases the cross-correlations are not significant and that longer time duration light curves are required.

142.03

Testing the Radiative-Driving Hypothesis of Quasar Outflows

Michele A. Stark¹, R. Ganguly¹, S. C. Gallagher², R. Gibson³, M. S. Brotherton⁴ ¹University of Michigan - Flint, ²University of Western Ontario, Canada, ³University of Washington, ⁴University of Wyoming.

Exhibit Hall

Outflows are seen prominently in the UV spectra of Broad Absorption Line (BAL) QSOs. Models of radiatively-driven outflows predict that the velocity should scale with UV luminosity. Observations show that the UV luminosity only provides a cap to the velocity. One explanation is that the X-ray absorbing gas in an individual quasar provides a shield that improves its radiative-driving efficiency. That is, quasars with thick shields can accelerate gas to higher velocity. X-ray observations of BALQSOs support this in the sense that BALQSOs with more soft X-ray absorption tend to have higher velocity outflows. But there is much scatter in this trend, making the underlying physics difficult to extract. To combat this, we conducted an experiment using exploratory Chandra-ACIS observations of 12 carefully-selected z=1.7-2.0 BALQSOs. These BALQSOs were chosen to have very narrow ranges in (1) UV luminosity, (2) UV spectral shape, and (3) absorption velocity width. Within this otherwise uniform sample, the outflow velocities range from 4500km/s to 18000km/s, a factor of four. All objects are detected in the full band (0.5-8keV), with count rates in the range (0.5-5)e-3 cps, and have hardness ratios in the range -0.6 to 0.3. We compare the X-ray brightnesses and spectral shapes of our sample with those of more diverse samples of BALQSOs.

We gratefully acknowledge support through Chandra grant GO9-0120X.

142.04

Toward a Prescription for Feedback from Quasar Outflows

Rajib Ganguly¹, M. Bourjaily¹, J. Munsell¹, M. S. Brotherton², A. Bhattacharjee², J. Runnoe², J. C. Charlton³, M. Eracleous³

¹Univ. of Michigan-Flint, ²Univ. of Wyoming, ³The Pennsylvania State University. Exhibit Hall

Models have shown that guasars are a crucial ingredient in the evolution of massive galaxies. Outflows play a key role in the story of quasars and their host galaxies, by helping regulate the accretion process, the star-formation rate and mass of the host galaxy (i.e., feedback). The prescription for modeling outflows as a contributor to feedback requires knowledge of the outflow velocity, distance, geometry, and column density. In particular, we need to understand how these depend on physical parameters and how much is determined stochastically (and with what distribution). For this purpose, we are examining a sample of 14000 z=1.7-2.0 guasars from the Sloan Digital Sky Survey. This redshift range permits the following from the SDSS spectra: (1) separation of objects that do and do not exhibit outflows; (2) classification/measurement of outflow properties (ionization, velocity, velocity width); and (3) estimates of the quasar black hole mass. To this, we are adding photometry from GALEX, 2MASS, and ROSAT in an effort to characterize more fully the quasar SEDs. ROSAT photometry provides estimates of the level of soft X-ray absorption, which helps regulate the velocity of outflows. GALEX photometry samples the extreme ultraviolet range where several high ionization species, that may be present in the outflows, absorb light. 2MASS photometry samples the rest-frame optical, where the effects of absorption and dust reddening are minimal, yield better estimates of the bolometric luminosity (hence, Eddington ratio). In this poster, we will present preliminary measurements of the amount of absorption in the soft X-ray and extreme ultraviolet bands as a function of both outflow properties and quasar physical properties.

This material is based upon work supported by the National Aeronautics and Space Administration under Grant No. 09-ADP09-0016 issued through the Astrophysics Data Analysis Program.

142.05

Recent Star-formation in Post-Starburst Quasars

Shonda Townsend¹, R. Ganguly¹, A. Strom², S. Cales³, M. S. Brotherton³

¹University of Michigan - Flint, ²University of Arizona, ³University of Wyoming. Exhibit Hall

Post-Starburst Quasars (PSQ, alternatively Q+As) show simultaneously the spectrum of a massive A-type stellar population and a quasar. The prototype PSQ, UNJ1025-0040, shows a UV excess over the quasar

spectrum, indicating more recent star-formation (Brotherton et al 2002). To gauge the frequency and distribution of these younger stellar populations in PSQs, we have collected GALEX (GR45) and 2MASS photometry for 409 objects. The objects are catalog 609 spectroscopically-selected PSQs from Brotherton et al. (2010) that uses similar criteria as Zabludoff et al. (1996) for post-starburst galaxies (PSG, E+A). For comparison, we have compiled two samples: (1) 16,000 guasars that is matched in redshift (0.01-0.7) and Sloan-u magnitude (16.1-21.2), which is blueward of the Balmer edge and provides the least contamination from the massive stellar population; and (2) 500 PSGs from Goto et al. (2007). 389 (55) PSQs show an NUV (FUV) excess over the expected UV flux if the underlying guasar were ``normal." 126 (460) objects show an NUV (FUV) decrement. The observed NUV to u-band flux ratio of the median PSQ rises from ~1 at z=0.01 to 2.5 at z=0.4, while the same for the median QSO remains at ~1. The observed FUV to u-band flux ratio of the median QSO rises slightly from ~0.6 to ~0.8 over the redshift range 0.05-0.2, whereas the median PSQ is nearly a factor of three lower. The disparity between the median PSQ and QSO suggests the presence of young stars that add in NUV light, but not FUV light. To quantify the youth and mass of this putative population, we will present preliminary efforts to model PSQs using two simple stellar populations, an underlying quasar, and dust reddening. We acknowledge funding from GALEX through grant NNX10AC63G.

142.06

Parsec-Scale Localization of the Quasar SDSS J1536+0441A, a Candidate Binary Black Hole System J. M. Wrobel¹, A. Laor²

¹NRAO, ²Technion, Israel. Exhibit Hall

The radio-quiet quasar (RQQ) SDSS J1536+0441A shows two broad-line emission systems, recently interpreted as a binary black hole (BBH) system with a subparsec separation; as a double-peaked emitter (DPE); or as both types of systems. The NRAO VLBA was used to search for 8.4 GHz emission from SDSS J1536+0441A, focusing on the localization region for the broad-line emission, of area 5400 mas² (0.15 kpc²). One source was detected, with a diameter of less than 1.63 mas (8.5 pc) and a brightness temperature $T_b > 1.2 \times 10^7$ K. New NRAO VLA photometry at 22.5 GHz, and earlier photometry at 8.5 GHz, gives a rising spectral slope of alpha = 0.35+/-0.08. The slope implies an optically thick synchrotron source, with a radius of about 0.04 pc, and thus $T_b \simeq 4.8 \times 10^{10}$ K. The implied radio sphere at the rest frequency 31.2 GHz has a radius of 800 gravitational radii, just below the size of the broad line region in this object. Observations at higher frequencies with the EVLA and ALMA can probe whether or not the radio sphere is as compact as expected from the coronal framework for the radio emission of RQQs. The NRAO is a facility of the NSF operated under cooperative agreement by AUI.

142.07

Galaxy-scale Clouds Of Ionized Gas Around Agn - History And Obscuration

Drew Chojnowski¹, W. C. Keel²

¹*Texas Christian University,* ²*University of Alabama.*

Exhibit Hall

Motivated by the discovery of Hanny's Voorwerp, a 45-kpc highly-ionized cloud near the spiral galaxy IC 2497, and accompanying evidence for strong variability of its AGN over 10^5 year scales, members of the Galaxy Zoo project have carried out surveys for similar (albeit smaller) ionized clouds around galaxies both with and without spectroscopic AGN. The color-composite SDSS images detect strong [OIII] in the *g* band at low *z*, allowing a useful color search of Galaxy Zoo targets. In addition, a targeted search was made of over 16,000 spectroscopic AGN and candidates. We used SDSS data to produce crude [OIII] images of the top candidates, and obtained long-slit optical spectra from KPNO and Lick for 30 of the most promising. Roughly half of the spectra showed extended [OIII] λ 5007 emission, some exceeding 30

kpc in radial extent. Of the 16 extended clouds we identified, 11 lie in strongly interacting or merging systems, probably because these events leave cold gas out of the plane to be ionized. Most nuclei of extended cloud hosts are type 2 Seyferts. We consider the energy budgets, between ionizing luminosity required for the most distant line emission and the FIR output of the nucleus, to see whether any suggest strong variability rather than obscuration. Several galaxies have such strong mismatches that obscuration alone becomes implausible as an explanation for the strong ionizing continuum, and are candidates for fading events similar to that in IC 2497 and Hanny's Voorwerp. This project was funded by the National Science Foundation Research Experiences for Undergraduates (REU) program through grant NSF AST-1004872.

142.08

The History And Environment Of A Faded Quasar: HST Observations Of Hanny's Voorwerp And IC 2497 William C. Keel¹, C. Lintott², K. Schawinski³, V. Bennert⁴, D. Thomas⁵, A. Manning¹, S. D. Chojnowski⁶, H. van Arkel⁷, S. Lynn⁸, Galaxy Zoo team

¹Univ. of Alabama, ²Adler Planetarium, ³Yale Univ., ⁴UCSB, ⁵Univ. of Portsmouth, United Kingdom, ⁶Texas Christian Univ., ⁷CITAVERDE College, Netherlands, ⁸Oxford Univ., United Kingdom. Exhibit Hall

Perhaps the signature discovery of the Galaxy Zoo citizen-science project has been Hanny's Voorwerp, high-ionization cloud extending 45 kpc from the spiral galaxy IC 2497. It must be ionized by a luminous AGN, either deeply obscured or having dimmed dramatically within 200,000 years. We explore this system using HST imaging and spectroscopy. The disk of IC 2497 is warped, with complex dust absorption near the nucleus; the near-IR peak coincides closely with the VLBI core marking the AGN. STIS spectra show the AGN as a low-luminosity LINER, with ionization parameter log U= -3.5, matching its weak X-ray emission. The nucleus is accompanied by an expanding loop of ionized gas \sim 500 pc in diameter, opposite Hanny's Voorwerp. The loop's Doppler span 300 km/s implies kinematic age < 700,000 years. We find no high-ionization gas near the core, further evidence that the AGN is seen at a low radiative output (perhaps now dominated by kinetic energy). [O III] and H α +[N II] ACS images show fine structure in Hanny's Voorwerp, including limb-brightened sections suggesting modest interaction with a galactic outflow. We identify small regions ionized by recent star formation, unlike the AGN ionization of the overall cloud. These H II regions contain blue continuum objects, consistent with young stellar populations; these occur where projected closest to IC 2497, perhaps meaning that the star formation was triggered by compression from an outflow. The ionization-sensitive [O III]/Hα ratio shows broad bands across the object, and no discernible pattern with emission-line structures or near the prominent "hole" in the ionized gas. These results fit with our picture of an ionization echo from an AGN whose ionizing luminosity has dropped by a factor >100 within the last 200,000 years. Such rapid fluctuations in luminosity could alter our understanding of AGN demographics. Supported by NASA/STScl.

142.09

Twenty-Year Optical Variability of The Blazar PKS 1749+096: Exponential Outbursts?

Thomas J. Balonek¹, M. T. Lam¹, P. A. Patrick¹, E. L. Scott¹, A. J. Kaercher¹, J. Rupert², T. Taber², P. Hegel³, Y. H. N. Tam⁴, A. Morin⁵, K. Levandowski⁶, E. L. Graber⁷, T. S. Quirk⁸

¹Colgate Univ., ²Vassar Coll., ³Wesleyan Univ., ⁴Williams Coll., ⁵RPI, ⁶Wellesley Coll., ⁷Univ. Michigan, ⁸Siena Coll..

Exhibit Hall

We present the twenty-year R-band optical variability light curve for the BL Lac type quasar PKS 1749+096. We investigate the characteristic timescales and intensity of outbursts and flares by fitting exponential profiles to the variations. PKS 1749+096 underwent strong optical outbursts during the

summers of 2007 and 2008, reaching its brightest optical level in two decades, and exhibited an inactive period during summer 2009. We compare these two outbursts with lower amplitude well-sampled variations in 2000 through 2003. Observations were obtained as part of the intensive blazar variability monitoring program at the Colgate University Foggy Bottom Observatory (FBO). We gratefully acknowledge support for student research through an REU grant to the Keck Northeast Astronomy Consortium from the National Science Foundation, the NASA / New York Space Grant, and the Justus and Jayne Schlichting Student Research Fund at Colgate University.

142.10

Time Series Analysis of the Quasar PKS 1749+096

Michael T. Lam¹, T. J. Balonek¹

¹Colgate University.

Exhibit Hall

Multiple timescales of variability are observed in quasars at a variety of wavelengths, the nature of which is not fully understood. In 2007 and 2008, the quasar 1749+096 underwent two unprecedented optical outbursts, reaching a brightness never before seen in our twenty years of monitoring. Much lower level activity had been seen prior to these two outbursts. We present an analysis of the timescales of variability over the two regimes using a variety of statistical techniques. An IDL software package developed at Colgate University over the summer of 2010, the Quasar User Interface (QUI), provides effective computation of four time series functions for analyzing underlying trends present in generic, discretely sampled data sets. Using the Autocorrelation Function, Structure Function, and Power Spectrum, we are able to quickly identify possible variability timescales. QUI is also capable of computing the Cross-Correlation Function for comparing variability at different wavelengths. We apply these algorithms to 1749+096 and present our analysis of the timescales for this object. Funding for this project was received from Colgate University, the Justus and Jayne Schlichting Student Research Fund, and the NASA / New York Space Grant.

142.11

Feedback from radio-quiet quasars

Nadia L. Zakamska¹, J. E. Greene² ¹*KIPAC/Stanford*, ²*UT Austin*.

Exhibit Hall

The correlations between properties of supermassive black holes and stellar spheroids in nearby galaxies strongly suggest that there is a physical connection between these two components, even though their masses and physical scales are vastly different. There is growing evidence that radio-loud active galactic nuclei exert a strong feedback on the gas in their host galaxies, providing a possible mechanism for such connection. However, as only a minority of active galaxies are radio-loud at any given time, the radio-loud feedback may only be a part of the explanation. Here we report the discovery of powerful outflows from radio-quiet quasars observed in the emission lines of the photo-ionized gas.

142.12

Optical Spectra of the Teacup AGN

Justin Gagne¹, D. M. Crenshaw¹, W. C. Keel², T. C. Fischer¹

¹Georgia State University, ²University of Alabama.

Exhibit Hall

We present optical spectra of the "Teacup AGN", at a redshift of 0.085, discovered in the Sloan Digital Sky Survey (SDSS). The spectra were obtained with the Lowell Observatory 1.8-m Perkins telescope. The SDSS image shows a "handle" of ionized gas extending out to 5" (8 kpc) away from the nucleus of the galaxy. Our optical spectra reveal a myriad of emission lines resembling those from a typical Seyfert 2
galaxy. We use dereddened emission-line ratios to investigate the physical conditions in the gas and to estimate the luminosity of the hidden AGN.

142.13

Multi-wavelength Probes of Obscuration Towards the Narrow Line Region in Seyfert Galaxies

Steven B. Kraemer¹, H. Schmitt², M. Crenshaw³, M. Melendez⁴, J. Turner⁵, M. Guainazzi⁶, R. Mushotzky⁷ ¹Catholic University of America, ²NRL, ³Georgia State University, ⁴Johns Hopkins University, ⁵UMBC, ⁶ESA, Spain, ⁷University of Maryland.

Exhibit Hall

We present a study of reddening and absorption towards the Narrow Line Regions (NLR) in active galactic nuclei (AGN) selected from the Revised Shapley-Ames, 12mu, and Swift/Burst Alert Telescope samples. For the sources in host galaxies with inclinations of b/a > 0.5, we find that mean ratio of [O III] 5007 and [O IV] 28.59mu, is more than a factor of 2 lower in Seyfert 2s than Seyfert 1s. The combination of low [O III]/[O IV] and low [O III] 4363/5007 ratios in Seyfert 2s suggests more extinction of emission from the inner NLR than in Seyfert 1s. Similar column densities of dusty gas can account for the suppression of both [O III] 5007 and [O III] 4363. Also, we find that the X-ray line O VII 22.1A is weaker in Seyfert 2s, consistent with absorption by the same gas that reddens the optical emission. If Seyfert 2 galaxies have similar intrinsic [O III] spatial profiles as Seyfert 1s, the external dusty gas must extend far out along the NLR and, perhaps in the form of nuclear dust spirals.

142.14

Determining AGN Feedback Parameters from Seyfert Galaxy Outflows

D. Michael Crenshaw¹, S. B. Kraemer², H. R. Schmitt³, T. C. Fischer¹

¹Georgia State Univ., ²The Catholic University of America, ³Naval Research Laboratory. Exhibit Hall

Mass outflows of ionized gas, detected through Hubble Space Telescope observations of blueshifted UV absorption lines and spatially-resolved emission lines, are common in nearby AGN. We review the constraints that these observations place on the structure of AGN winds, and provide estimates of the mass outflow rates and kinematic luminosities needed for AGN feedback models.

142.15

Double-Peaked Emission Lines in the Seyfert Galaxy Markarian 78: Mass Outflows from a Single AGN Travis C. Fischer¹, D. M. Crenshaw¹, S. B. Kraemer², H. R. Schmitt³

¹Georgia State University, ²The Catholic University of America, ³Naval Research Laboratory. Exhibit Hall

We present a study of the outflowing ionized gas in the resolved narrow-line region (NLR) of Mrk 78 using observations from Space Telescope Imaging Spectrograph (STIS) and Faint Object Camera (FOC) aboard the Hubble Space Telescope (HST). We determine that the double set of emission lines seen in ground based observations are due to an asymmetric distribution of outflowing gas in the NLR. In successfully fitting a single AGN model to Mrk 78, we show that it is possible to explain double emission lines seen in radial velocity offsets of AGN similar to Mrk 78 without the requirement of dual supermassive black holes.

Quasars in the Extreme UV: Spectral Indices and Potential Emission Lines, and Implications for He II Reionization

David Syphers¹, S. Anderson², W. Zheng³, A. Meiksin⁴

¹University of Colorado, ²University of Washington, ³Johns Hopkins University, ⁴University of Edinburgh, United Kingdom.

Exhibit Hall

The extreme UV (EUV, <912 A) region of quasar spectra is poorly understood, because the high opacity of intervening hydrogen absorption systems makes it very difficult to observe. In the course of identifying a large number of new sightlines for the He II Gunn-Peterson test, we have amassed an unprecedentedly large collection of quasar spectra covering 250-500 A (rest frame). This allows us to examine emission lines in this largely unexplored region, as well as the average EUV spectral index. This continuum slope is poorly constrained, but vitally important for understanding the ionizing UV background in the IGM, as well as the progress of He II reionization. Our sample complements that of the few other EUV spectral index studies, which mostly extrapolate from longer wavelengths. Cloudy photoionization models of the broad emission line region (BELR) over a high-dimensional parameter space predict detectable He II Ly-alpha emission, with any other lines absent or very weak. Observationally, we find He II Ly-alpha is only rarely present, and sometimes other emission lines are present. We consider a number of possible explanations for weak He II Ly-alpha, including absorption from the IGM and absorption intrinsic to the quasar, and find that although no single explanation suffices, together they may. We find that BELR turbulence is an effective way of increasing the strength of metal lines relative to H and He, and may plausibly explain the presence of EUV metal lines. We offer a few, very tentative identifications of EUV metal lines seen in some spectra. Updates to ongoing HST He II studies will also be briefly described.

We gratefully acknowledge NASA/STScI funding for HST program numbers 10907, 11215, 11982, and 12178.

142.17

Variable High Velocity Winds from Broad Absorption Line Quasars

Kenza S. Arraki¹, D. Haggard², S. Anderson³, P. Green⁴, T. Aldcroft⁴ ¹New Mexico State University, ²Northwestern University, ³University of Washington, ⁴Harvard-Smithsonian Center for Astrophysics.

Exhibit Hall

We study broad absorption line quasars (BALQSOs) because these objects, in particular, probe the high velocity gas ejected by luminous accreting black holes. The variability timescales of BALs can help constrain the size, location, and dynamics of the emitting and absorbing gas near the supermassive black hole. We have obtained multi-epoch spectroscopy of seventeen BALQSOs from the Sloan Digital Sky Survey (SDSS) using the Fred Lawrence Whipple Observatory's 1.5m telescope's FAST Spectrograph. These objects were first identified as BALQSOs in SDSS, observed with Chandra, and then with FAST at 1, 3, 9, 27, and 81 day timescales. Additional observations are acquired for 1 and 2 year cadences. We also obtain a set of non-BAL quasar spectra of similar redshift and luminosity as controls. We identify significant variability and assess its magnitude and frequency in the observed spectra of our BAL QSOs and determine which constraints our investigations can put on the outflows impacting the BAL region.

The Western Radio Lobe of Fornax A: Nature of the X-ray Emission

Electra Panagoulia¹, P. Nulsen², R. Kraft², L. David², W. Forman², C. Jones², B. McNamara³ ¹University of Southampton, United Kingdom, ²Harvard Smithsonian Center for Astrophysics, ³Waterloo University, Canada.

Exhibit Hall

An XMM-Newton observation of the western radio lobe of Fornax A has cast doubt on previous interpretations of the X-ray emission as inverse Compton scattered cosmic microwave background radiation. Imaging and spectroscopy both support a thermal origin for at least part of the detected X-ray emission. However, analysis of the XMM-Newton data is complicated by a significant level of background flaring. We will present a new analysis of the X-ray data, paying careful attention to removal of background. Implications of these results for the radio lobe and its group environment will be discussed.

142.19

Using Non-linear X-ray Variability to Explore the Core of Active Galaxy 3C 390.3 Sean Quinn¹, K. Marshall²

¹Rochester Institute of Technology, ²Bucknell University.

Exhibit Hall

Luminous variability of active galaxies is a universal phenomenon; however, there is no universally accepted causal mechanism. This study investigated variability of the broad line radio galaxy 3C 390.3. We concentrated on variability in the X-ray regime (2-10 keV), which is quite rapid-a consequence of the radiation source being proximal to the super massive black hole. Such variability can be explained by accretion disk models; however, there are numerous plausible but physically distinct models. We sought to isolate a particular accretion model which accurately describes the X-ray features for this galaxy. After performing a detailed time series analysis, with a focus on linearity tests, our results imply with high confidence that a non-linear multiplicative model is generating the variability. Given this criterion, we assert that the propagating viscosity fluctuation model is best suited for describing the observed X-ray behavior of this galaxy.

This work was supported by the Bucknell University REU program which is funded by the National Science Foundation.

142.20

Fornax A's Western Radio Lobe Composition

Jason J. Kong¹, P. E. J. Nulsen², R. P. Kraft²

¹University of California at Berkeley, ²Harvard Smithsonian Astrophysical Observatory. Exhibit Hall

We present an analysis of the western radio lobe of Fornax A based on an XMM-Newton observation. We find little evidence for the inverse-Compton scattering of the cosmic microwave background as reported previously. The spectra in the energy range of 0.5-5 keV are well fitted by a thermal plus power law model for every spectral region we extracted. With a fixed photon index of 1.68, the X-ray flux density at 1 keV from the power law fit was measured to be < 28 nJy at the 90% confidence level, leading to a lower limit on the magnetic field in this region of 6 micro-Gauss. Our spectral fits suggest that there is hot gas surrounding the radio lobe. A filament of dense, cool gas extends from the central galaxy in the direction of the radio lobe of Fornax A. Spectral fits give a temperature of kT=0.76 keV over the radio lobe and kT=0.32 keV for the cool filament. The thermal emission from the radio lobe region is best explained as emission from a thin shell of shocked gas swept up by the rapidly expanding lobe. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 0754568 and by the Smithsonian Institution.

142.21

Eclipses of the Inner Accretion Disk in NGC 1365 by Broad Line Region Clouds Laura Brenneman¹, G. Risaliti¹, M. Elvis¹

¹Harvard-Smithsonian Center for Astrophysics.

Exhibit Hall

We present new data obtained from a Suzaku AO5 Long Program observation of NGC 1365, a unique source that has in the past displayed both a prominent, relativistically broadened iron line and evidence for Compton-thin and Compton-thick eclipses of the inner disk region. These eclipse events allow us to constrain the structure and geometry of the inner disk and the intrinsic absorber(s) with unprecedented detail, and enable us to rule definitively on the emission vs. absorption origin of the putative broad iron line in this source.

142.22

Evidence Against the Unification of Quasars and Radio Galaxies from a New Sample of Luminous Radio Sources

Todd A. Boroson¹

¹NOAO.

Exhibit Hall

A new sample of high-luminosity extragalactic (0.1 < z < 0.5) radio sources has been constructed using SDSS and three radio surveys: WENSS, NVSS, and FIRST. Initial matching of SDSS with WENSS (325 MHz), including the possibility of sources without radio cores, ensures that the sample is not contaminated by anisotropic radio core emission. This technique finds many more sources than existing catalogs based on SDSS matches with FIRST or NVSS. The resulting list comprises 86 objects in a complete sample having log luminosity density > 26.5 W/Hz at 325 MHz in the rest frame. An additional 26 objects are found that were targeted by SDSS as matches with FIRST or ROSAT sources. Optical properties (luminosities, spectral classification, emission line strengths) and radio properties (spectral index, source morphology, projected linear size) have been measured and tabulated. The distribution of projected linear sizes is particularly interesting; when divided into subsets with and without broad lines, the objects with broad lines (quasars) tend to have larger projected sizes at 1.4 GHz than those without broad lines (radio galaxies). The medians of the size distributions are 200 kpc for the radio galaxies (52 objects) and 350 kpc for the quasars (34 objects). This is different from the classic test by Barthel (1989) from which he argued that radio-loud quasars could be unified with radio galaxies by orientation.

142.23

Gamma-Ray Blazar Light Curves at 230 GHz from February 2009-November 2010

Ann E. Wehrle¹, A. C. Zook², M. A. Gurwell³, S. C. Unwin⁴

¹Space Science Institute, ²Pomona College, ³Harvard-Smithsonian Center for Astrophysics, ⁴Jet Propulsion Laboratory/Caltech.

Exhibit Hall

We present 230 GHz continuum fluxes of blazars on the Fermi LAT Monitored Source List and of several blazars added after the Fermi LAT team reported flaring activity. Our science goal is to determine how and where relativistic charged particles emit synchrotron radiation and also act as scatterers of low energy photons (from jets, dust, the Broad Line Region and the hot corona) up to gamma ray energies. The data were obtained at approximately two-three week intervals at the Submillimeter Array, beginning in February 2009 and ending in November 2010. This program provides more evenly and

frequently sampled data than the Submillimeter Array's ongoing flux density monitoring of quasars that are typically bright in the mm/submm bands, in order to optimally choose quasars for use as interferometric calibration sources (led by M. Gurwell (CfA); see

http://sma1.sma.hawaii.edu/callist/callist.html/). The resulting light curves may be correlated with Fermi LAT photometry, Swift and RXTE observations, and related ground based monitoring programs. From the comparison, time delays between high and low levels at different bands can be derived. We can also compare the relative amplitudes at millimeter and gamma ray bands of flaring and quiescent levels.

A. Wehrle acknowledges support from the NASA Space Interferometry Mission preparatory science program through JPL Subcontract 1283664 to the Space Science Institute.

142.24

Multi-Wavelength Variability of Fermi Selected Blazars

Meghan Frate¹, K. Marshall¹, M. Aller², H. Aller², H. Miller³, J. Eggen³, D. Gudkova³, H. Marine³, J. Maune³ ¹Bucknell University, ²U. of Michigan, ³GSU.

Exhibit Hall

It is known that blazars are among the most variable and luminous objects in the sky due to their orientation relative to our line of sight. Our work has been to map the variability in four energy bands to search for correlations, in hopes of finding better relationships between the energy bands and supplementing existing multi-wavelength studies. We've done this with seven blazars monitored by the Fermi Gamma-ray Space Telescope and collected radio, optical, and X-ray data. We found strong correlation between optical and gamma-ray emissions in most of our objects, with X-rays generally uncorrelated with all other wavelengths, and were able to match these results up to existing emission models.

142.26

Vri/gri Photometry And Polarimetry Of Blazars At The Table Mountain Observatory, 2005-2010

Alma C. Zook¹, M. M. Amezcua¹, M. W. Hasling¹, W. A. Morrison¹

¹Pomona College.

Exhibit Hall

We present VRI/*gri* photometry and polarimetry of several objects studied by the blazar monitoring program at Pomona College's Table Mountain Observatory, which has now been operating for six summers. Initially only VRI photometric observations were possible; a polarimeter was added and tested during the summer of 2007 and a set of *gri* filters added in 2008. A total of sixteen blazars have been monitored during this time, most notably 3C279, 1510-089, 1611+343, 1652+398 (= Mrk 501), 1727+502, 3C 371, 1959+650, and 3C 454.3. The blazar 3C454.3 is particularly interesting, since it has undergone two outbursts during the monitoring period, in May 2005 and July 2007.

142.27

Investigating The AGN Population In Cluster Environments Across Different Wavelengths

Eleanor Byler¹, D. Norman²

¹Wellesley College, ²NOAO.

Exhibit Hall

Currently, there is no complete picture of AGN formation and evolution in galaxy clusters. A general understanding of the AGN population has been impeded by cluster and selection biases and recent studies have shown that there is a large population of obscured or optically unremarkable AGN in galaxy clusters. We used SDSS data to look at the AGN distribution in 12 clusters over a range of redshifts (z = 0.16 - 0.35) and compared the optical and X-ray AGN content with that of six 'blank' fields. We found that on average the cluster fields had a small optical AGN excess as compared to blank fields. The AGN

population and distribution was also compared by cluster morphology, and non-virialized clusters were found to have a higher X-ray and optical AGN content than virialized clusters. We also compare our optical AGN to Gilmour et al.'s (2009) X-ray survey to compare assumptions made about cluster membership.

Byler was supported by the NOAO/KPNO Research Experiences for Undergraduates (REU) Program, which is funded by the National Science Foundation Research Experiences for Undergraduates Program and the Department of Defense ASSURE program through Scientific Program Order No. 13 (AST-0754223) of the Cooperative Agreement No. AST-0132798 between the Association of Universities for Research in Astronomy (AURA) and the NSF.

142.28

Unusual Swift-BAT Detected AGN

James Hogg¹, L. Winter¹

¹University of Colorado.

Exhibit Hall

The goals of our study were to analyze two odd AGN sources, NVSS 193013+341047 and IRAS 05218-1212, and determine if they were Compton-thick and low-redshift ERO analogs. The sources are strange because initial Swift XRT data lead us to believe the sources could be Compton-thick, typical of Seyfert 2 galaxies but they have broadlines in their optical spectra, typical of Seyfert 1 galaxies. These are two contradictory categorizations which made these sources very unique. In addition to the puzzling spectra, their SEDs are similar to the SED of a high redshift ERO and unlike things we typically see at their lower redshift. In order to study these sources further, we acquired and reduced higher quality XMM-Newton X-ray data. We then modeled the two spectra using XSPEC and learned that both sources had many complex components. From the higher quality data, we determined that they were heavily obscured, but not to the point of being considered Compton-thick. Both of the spectral fit models were heavily dependent on partial covering and reflection models. We found very high covering fractions and high column densities in both of our models, which was consistent with the galaxies being heavily obscured as we initially assumed. Further, we believe that future study of the sources as low-redshift ERO analogs can assist in better understanding of the early universe EROs we often see. If further study confirms the analogous relationship, these sources provide a great opportunity to add to our scientific knowledge about ERO evolution.

142.29

XMM Follow-Up Observations of Three Swift BAT-Selected Active Galactic Nuclei

Margaret Trippe¹, C. Reynolds¹, M. Koss¹, R. Mushotzky¹, L. Winter²

¹University of Maryland, ²University of Colorado.

Exhibit Hall

We present follow-up XMM observations of three AGN that were selected from the Swift BAT hard X-ray survey as candidate Compton-thick AGN: ESO 417-G006, IRAS 05218-1212, and MCG -01-05-047. The XMM spectra, however, rule out reflection-dominated models based on the weakness of the observed Fe K-alpha lines. Instead, the spectra are well-fit by a model of a powerlaw continuum obscured by a Compton-thin absorber, plus a soft excess. This result is consistent with previous follow-up observations of two other flat-spectrum BAT detected AGN. Thus, out of the six AGN in the 22-month BAT catalog with flat Swift XRT spectra, all five that have had follow-up observations are not likely Compton-thick.

Variability in Quasar Broad Absorption Line Outflows

Daniel M. Capellupo¹, F. Hamann¹, J. C. Shields², T. A. Barlow³, J. P. Halpern⁴, P. Rodriguez Hidalgo⁵ ¹University of Florida, ²Ohio University, ³California Institute of Technology, ⁴Columbia University, ⁵Pennsylvania State University.

Exhibit Hall

Broad absorption lines (BALs) in quasar spectra identify high velocity outflows that likely exist in all quasars and could play a major role in feedback to galaxy evolution. Studying the variability in these BALs can help us understand the structure, evolution, and basic physical properties of these outflows. We are conducting an ongoing BAL monitoring program that has produced over 160 spectra of 24 luminous quasars at z of 1.2-2.9, covering time-scales from 7 days to 7.7 years in the quasar rest-frame. We first investigate changes in the CIV 1550A BALs, and we see a variety of phenomena, including some absorption that either appeared or disappeared completely and other BALs that did not change at all over the whole observation period. The incidence of variability declines from 65% to 39% between the time domains of several years and a few months, and typically, only portions of the BAL troughs vary. We also compare the variability in the CIV 1550A BAL to the SiIV 1400A BAL to help distinguish between moving clouds and ionization changes as the cause of the variability. Using the multiple epochs of data from our program, we can characterize the variability over time in individual objects. Our most recent data covers the poorly sampled time domain of <1 month in the quasar rest-frame, which we can use to put constraints on the location of the outflowing gas.

142.31

Multi-frequency Optical-depth Maps And The Case For Free-free Absorption In Two Compact Symmetric Objects: 1321+410 And 0026+346

Thomas M. Perry¹, J. M. Marr¹, J. W. Read¹, G. B. Taylor²

¹Union College, ²University of New Mexico.

Exhibit Hall

We obtained VLBI observations at six frequencies of two Compact Symmetric Objects, 1321+410 and 0026+346. By comparing the lower frequency maps with spectral extrapolations of the higher frequency maps, we produced maps of the optical depth as a function of frequency.

The optical-depth maps of 1321+410 are strikingly uniform, consistent with a foreground screen of absorbing gas; the optical depths as a function of frequency are consistent with free-free absorption; and no net polarization was detected. We conclude that the case for free-free absorption in 1321+410 is strong.

The optical-depth maps of 0026+346 exhibit structure but the morphology does not correlate with that in the intensity maps, in conflict with that expected in the case of synchrotron self-absorption. No net polarization was detected. The frequency dependence of the optical depths does not fit well to a simple free-free absorption model, but this does not take into account possible structure in the absorbing gas on smaller scales. We conclude that free-free absorption by a thin amount of gas with structure on the scale of our maps and smaller is possible in 0026+346, although no definitive conclusion can be made. A compact feature between the lobes in 0026+346 has an inverted spectrum even at the highest frequencies, suggesting that this component is synchrotron self-absorbed. We infer this to be the location of the core. We estimate an upper limit to the magnetic field in the core of 50 Gauss at a radius of 1 pc.

This research was supported by an award from the Research Corporation, a NASA NY Space Grant, and a Booth-Ferris Research Fellowship. The VLBA is operated by the National Radio Astronomy Observatory, a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

Polarized Radio Source Counts and the Evolution of Galactic Magnetism

Christopher A. Hales¹, B. M. Gaensler², R. P. Norris³, E. Middelberg⁴

¹The University of Sydney / Australia Telescope National Facility, Australia, ²The University of Sydney, Australia, ³Australia Telescope National Facility, Australia, ⁴University of Bochum, Germany. Exhibit Hall

Polarized radio source counts can address important unsolved problems in astrophysics such as the fundamental origin and subsequent evolution of large-scale coherent magnetic fields observed in galaxies, which remain poorly constrained by observational data.

Here we present differential source counts of polarized radio galaxies using the Australia Telescope Compact Array, where we have imaged two 3.5 square degree fields at 1.4 GHz to a depth of ~20 microjanskys per beam in polarization. We discuss the nature of our faint polarized radio sources (which extend beyond z~2) using multiwavelength cross-identifications, and investigate the distribution of fractional polarization for our sources. Our polarized source counts can be used to place immediate constraints on evolutionary models of radio sources as well as the evolution of their magnetic fields with cosmic time.

142.33

A Stochastic Model for the Luminosity Fluctuations of Accreting Black Holes

Brandon C. Kelly¹, M. Sobolewska¹, A. Siemiginowska¹

¹Harvard-Smithsonian Center for Astrophysics.

Exhibit Hall

I will present a new statistical model for the X-ray fluctuations of accreting black holes. The model is formulated in the time domain via a set of stochastic differential equations, and fitting the model is done in the time domain via a likelihood-based approach. Out technique is not biased by red noise leak, aliasing, irregular sampling, and measurement error, and is computationally efficient. We apply our model to the RXTE+XMM X-ray lightcurves of 10 local AGN and show that our model is both a good fit to the data, and is able to recover previous results with increased accuracy. We find a tight anti-correlation between the black hole mass and the amplitude of the driving noise field in our model, which is proportional to the amplitude of the high frequency X-ray PSD, and we estimate that this parameter gives black hole mass estimates to within ~ 0.2 dex precision.

142.34

Modeling the Distribution of Linear and Circular Polarization from AGN Jet Cores Christopher B. Wotta¹, D. C. Homan¹, M. L. Lister²

¹Denison University, ²Purdue University.

Exhibit Hall

We present the results of full radiative transfer simulations of AGN jet cores to study the common physical properties of jets, such as their magnetic field structure and particle properties, that may be responsible for the observed distributions of polarization. To constrain these values we compare the results of our simulations to the first epoch MOJAVE observations of a complete, flux-density limited sample of AGN jets at 15 GHz. A key feature of the observational data is a lack of correlation between observed linear and circular polarization, and we found that this lack of correlation could be reproduced in our simulations if the circular polarization is produced stochastically, likely by Faraday conversion, in a magnetic field dominated by tangled components on a length scale of $\sim 1/15$ to 1/20 of a jet diameter. The tangled field components must also be shocked to explain the levels of observed linear polarization. We note that other possible explanations exist for the lack of observed correlation between linear and circular polarization, including un-resolved sub-structure and Faraday depolarization in external screens. This work has been supported by National Science Foundation grants AST-0707693 and AST-0807860.

142.35

Hydrodynamic Simulations of Double-Bent Radio Sources

Jacob Miller¹, B. Morsony¹

¹University of Wisconsin.

Exhibit Hall

Using three-dimensional hydrodynamic modeling, we simulate the development and evolution of Active Galactic Nuclei in galaxy groups in order to better understand the relationship between jet curvature and various properties of the Intergalactic Medium and of the AGN itself, with an emphasis on the use of radius of curvature as a density probe of the IGM.

142.36

Hubble/COS Observations of AGN Ionizing Continua

Matthew L. Stevans¹, J. M. Shull¹, C. W. Danforth¹

¹University of Colorado - Boulder.

Exhibit Hall

The high-throughput Cosmic Origins Spectrograph (COS) installed on the Hubble Space Telescope (HST) allows us to obtain high-quality UV spectra of active galactic nuclei (AGN), many of which served as background targets for studies of the low-redshift intergalactic medium (IGM). We present power-law continuum fits for a sample of 13 AGN with redshifts 0.0296 < z < 0.852, sufficient to explore their far ultraviolet (FUV) and extreme ultraviolet (EUV) continua. New spectra from HST/COS provide spectral coverage in the rest-frame Lyman continuum of AGN at z > 0.24, with high sensitivity and moderate resolution (20 km/s) in the G130M grating. This allows broad emission lines (Ne VIII, O IV) to be resolved. In cases when Far Ultraviolet Spectroscopic Explorer (FUSE) and International Ultraviolet Explorer (IUE) data are available, we create and fit composite spectra covering between 900 - 3300 Å; in the observed frame. We compare COS-based power-law spectra to these data. Describing the EUV continuum fluxes by a power-law spectrum, $F_v = A v^{\alpha}$ with index α , gives insight into the formation of emission lines, defines the "big blue bump" in the spectral energy distribution of AGNs, and constrains the ionization state of the IGM. We examine our results for correlations of spectral slope with redshift and compare our results to previous spectral fits from HST/FOS (Telfer et al. 2002, ApJ, 565, 773) and FUSE (Scott et al. 2004, ApJ, 615, 135). This work is supported by the COS-support grant from the STScI (NNX08-AC14G).

142.37

Multi-wavelength Monitoring of 6 Gamma-ray Blazars at Maria Mitchell and Other Observatories Stephanie Sallum¹, S. G. Jorstad², A. P. Marscher², G. Walker³, V. Strelnitski³, V. M. Larionov⁴ ¹*MIT & Maria Mitchell Obs.,* ²*Boston U.,* ³*Maria Mitchell Obs.,* ⁴*St. Petersburg U., Russian Federation. Exhibit Hall*

We have observed 6 gamma-ray bright blazars in the B and R bands (and V and I bands for some sources) using the Maria Mitchell Observatory 17" Dall-Kirkham and 24" Ritchey-Chretien reflectors during 2010. In all of the blazars, we have detected variability on a timescale of days to weeks; in OT+081, a dramatic outburst occurred in August 2010 when the flux at R band increased by 3.5 magnitudes. We supplement our optical R band observations with data taken at other telescopes, including RXTE, Swift, and public data from the Fermi Gamma-Ray Space Telescope's Large Area Telescope. This allows us to form the spectral energy distribution (SED) of each blazar. We further support our dataset by comparing our multi wavelength light curves with 43 GHz VLBA images of the radio jets at 43 GHz for all of the objects. We discuss the connection between variations in the optical

bands and at other frequencies, as well as the physical constraints that time delays and SEDs impose on the high-energy emission mechanism.

The research at Boston U. was supported by NSF grant AST-0907893 and NASA grant NNX08AV65G (Fermi). The research at Maria Mitchell Obs. was supported by the NSF/REU grant AST-0851892 and by the Nantucket Maria Mitchell Association.

142.38

A Spitzer Survey of Hot Spots in Radio Lobes

Michael W. Werner¹, V. Gorjian¹, J. Livingston¹, D. Jones¹, D. Murphy¹, D. Meier¹, C. Lawrence¹, A. Readhead²

¹JPL/Caltech, ²Caltech.

Exhibit Hall

We present the results of a survey at infrared wavelengths of the emission from hotspots in the lobes and jets of energetic radio sources. Our sample is chosen from the work of Hardcastle et al (2004), who analyze x-ray and radio data on a number of hot spots. For nine hot spots we used infrared data from the Spitzer archive - generally in all four IRAC bands - while for another 17 we carried out new observations with Warm Spitzer in the IRAC band at 3.6um. For 17 hotspots, 7 archival and 10 from the warm mission, we have infrared detection(s) and present an x-ray/infrared/radio SED, often with additional optical data also presented by Hardcastle et al.

For another 9 hotspots (2 archival and 7 newly observed) we have only upper limits from the Spitzer observations to go with the x-ray and radio detections. We compare the multiwavelength SEDs with the predictions of synchrotron self Compton and pure synchrotron models for the hotspots.

This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration

142.39

Optical Analysis Of A Binary Black Hole's Host Galaxy 0402+379

Steffanie Peterson¹, R. Zavala²

¹Northern Arizona University, ²United States Naval Observatory Flagstaff Station. Exhibit Hall

We present results from optical data analysis of the active galactic nucleus (AGN) host galaxy 0402+379. This AGN hosts two binary black holes, which have a projected separation of only 7.3 parsecs. This separation is two times closer than any other known system. The data were taken with WIYN in December 2008 in broadband filters g, r and i as well as in narrowband filters W13, W25, W26 and K814. We analyze the narrowband data to find regions of H α , NII and SII emission, indicating star forming regions. We determine the stellar age distribution within the host galaxy from the g/r/i colors. We conclude that the morphology of the host galaxy is elliptical using De Vaucouleurs' Law with our calculated surface brightness. We use this morphological information to estimate the relative date of the merger to be approximately 2 Gyr ago. We also conclude that a third galaxy is interacting with the host galaxy, which may provide a means of reducing the system's angular momentum and facilitating coalescence.

WFC3 Imaging Of z=6 QSO Hosts: A Method For PSF Characterization And Subtraction Matt Mechtley¹, R. A. Windhorst¹, G. Schneider², S. H. Cohen¹, X. Fan², N. P. Hathi³, W. C. Keel⁴, A. Koekemoer⁵, H. Rottgering⁶, R. E. Ryan⁷, D. P. Schneider⁸, M. A. Strauss⁹, H. Yan¹⁰ ¹Arizona State University, ²University of Arizona, ³Carnegie Observatories, ⁴University of Alabama, ⁵Space Telescope Science Institute, ⁶University of Leiden, Netherlands, ⁷University of California, Davis, ⁸Pennsylvania State University, ⁹Princeton University, ¹⁰The Ohio State University. Exhibit Hall

We present an observation and analysis plan for using the Wide Field Camera 3 IR Channel on the Hubble Space Telescope to carefully characterize and subtract the central point source from a redshift 6 QSO, in an attempt to image and conduct photometry on the underlying host galaxy.

We discuss parameters affecting measurement of the instrument point spread function (PSF), including thermally-induced secondary mirror de-focus ("spacecraft breathing"), object spectral slope, and IR channel image persistence. We describe in detail our plan to address these effects or measure them onorbit, and the criteria used to select the star with which we will make these PSF measurements. We also present our data analysis strategy, including models of breathing-induced PSF variation, and point source subtraction in simulated images. Depending upon the HST cycle 18 observation schedule, we will also discuss preliminary results if our first set of data is available. Support for HST GO program #12332 is provided by NASA through a grant from the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS 5-26555.

142.41

Radio Band Linear Polarization as a Probe of the Origin of Gamma-Ray Emission from Blazars Margo F. Aller¹, P. A. Hughes¹, H. D. Aller¹

¹Univ. of Michigan.

Exhibit Hall

To test the hypothesis that shocks play a role in the production of the gamma-ray flares detected by Fermi and to identify jet conditions during gamma-ray flares, we are intensively monitoring the linear polarization and total flux density of a core group of about two dozen radio-and-gamma-ray-bright AGN with the University of Michigan radio telescope to look for the expected shock signature: an increase in the degree of linear polarization and an ordered swing in electric vector position angle. We have observed increases in fractional linear polarization of order ten degrees and swings in electric vector position angle of order tens of degrees in several sources during gamma-ray flares. We present centimeter-band light curves for OJ287, PKS 1510-089, and OT 081 illustrating this signature and compare the spectral evolution apparent in the light curves with simulations from new radiative transfer calculations allowing for the propagation of shocks in the relativistic jet outflows at any orientation to the flow direction. These simulations are able to reproduce the primary features of the observed light curves.This research was supported by NASA Fermi grants NNX09AU16G and NNX10AP16G, NSF grant AST-0607523, and by the University of Michigan.

142.42

AGN Inner Structure with NuSTAR

Martin Elvis¹, L. Brenneman¹, M. Young², F. Civano¹, G. Risaliti¹, D. Stern³, F. Harrison³, NuSTAR Team ¹*Harvard-Smithsonian CfA*, ²*Penn State University*, ³*California Institute of Technology*. *Exhibit Hall*

The inner structure of AGNs has a standard model, but the model is poorly tested. The model is that of an accretion disk surrounded by a hot corona. The disk produces the primary optical and UV emission,

the corona upscatters these photons to X-rays, and a fraction of those X-rays are re-processed in the disk, which fluoresces to produce the Compton Hump (E>10keV) and an Fe-K emission line that is broadened by disk rotation and general relativity. Since few corona temperatures have been measaured, we cannot separate the Compton y-parameter into its temperature (kt) and optical depth (Tau) components. As we lack high signal-to-noise >10keV spectra the parameters of the red wing to the 6.4keV Fe-K line are poorly determined in all but a few cases, limiting our knowledge of the disk inner radius and black hole spin - or our ability to test alternative, e.g. multi-Nh screens.

NuSTAR will provide the first high S/N spectra of AGNs above 10keV. We present detailed simulations that demonstrate that the kT-Tau degeneracy can be very cleanly broken. In conjunction with Suzaku or XMM-Newton spectra we show that the red wing Fe-K profile can be exquisitely determined, giving the black hole spin parameter with small uncertainties. We also show that NuSTAR can span wide ranges of black hole mass and Eddington ratio with a reasonable observing program.

142.43

Determination of the Infrared Luminosity of Active Galactic Nuclei (AGN)

Varoujan Gorjian¹, K. Meredith², H. Petach², E. Ramseyer², T. Spuck², M. Abajian³, NITARP Luminous Data Miners Team

¹JPL, ²NITARP, ³NITARP/IPAC.

Exhibit Hall

Using archival data from the Spitzer and GALEX Space Telescopes we have plotted a UV-IR colormagnitude diagram for AGN. The previous difficulty in determining the IR luminosity of AGN using this technique has been that AGN have varying levels of obscuration in the UV, also they are variable and previous observations were often taken at widely differing times. As a result, color-magnitude diagrams sometimes had UV and IR data points acquired decades apart. These issues were mitigated in this study i) by using data that were collected much closer in time to each other, since both telescopes were launched and carried out most of their observations within the same 5 year period and ii) by choosing Type I AGN, which show the least amount of obscuration.

142.44

Observations Of Gamma-ray Loud Blazars With The VLBA At 5 GHz

Justin Linford¹, G. B. Taylor¹, R. Romani², A. C. S. Readhead³, R. Reeves³, J. L. Richards³, J. F. Helmboldt⁴ ¹University of New Mexico, ²Stanford University, ³California Institute of Technology, ⁴Naval Research Laboratory.

Exhibit Hall

The Fermi Gamma-ray Space Telescope has been scanning the sky for more than a year. About half of the sources detected by Fermi's Large Area Telesope (LAT) are active galactic nuclei (AGN). Nearly all of these gamma-ray loud AGN are blazars; strong, compact radio emitters that exhibit variability in their flux and apparent superluminal motion in their jets. Several groups are currently monitoring the radio properties of these gamma-ray loud blazars. We present results from both archival and contemporaneous observations of ~200 LAT-detected blazars using the Very Long Baseline Array (VLBA) at a frequency of 5 GHz (wavelength of 6 cm). Our large, flux-limited sample provides unique insights into the mechanism that produces strong gamma-ray emissions. We explore the parsec-scale properties of the cores and jets of these highly energetic objects, including core polarization. We compare the gamma-ray loud blazars to their gamma-ray quiet counterparts in the VLBA Imaging and Polarimetry Survey (VIPS). We also investigate the differences between the BL Lacertae objects (BL Lacs) and flat-spectrum radio quasars (FSRQs).

142.45 Emission Line Properties of a Low-Redshift Quasar Sample Amanda Truitt¹, K. M. Leighly¹ ¹University of Oklahoma.

, Exhibit Hall

We report the results of analysis of a sample of 81 low-redshift quasar spectra drawn principally from the Sloan Digital Sky Survey. The spectra were chosen to have sufficiently narrow lines that the FeII multiplets can be discerned, and to be minimally contaminated by galaxy emission. We fit the spectra uniformly with a model consisting of a power law, FeII templates, and Balmer lines, and we include [OIII] even when we cannot identify the line in the spectrum by eye.

We confirm some previously known correlations, and find some new ones. We confirm a strong correlation between H β FWHM and monochromatic luminosity at 5500 Angstroms, but we also find a strong correlation between [OIII] FWHM and luminosity. We confirm a correlation between [OIII] blueshift and [OIII] FWHM, but we extend that correlation to larger blueshifts (up to ~900 km/s) and larger velocity widths (up to >2000 km/s). This result is a consequence of our model fitting approach, and we note that the [OIII] component is generally statistically significant in the fit. We also confirm a strong correlation between power law slope and luminosity.

We investigate the properties of the Balmer lines in this sample using a Boltzmann plot approach. While the Balmer lines may not be emitted by thermal gas, we find that the temperature inferred is related to the Balmer line properties because objects with high temperatures exhibit Balmer continuum while objects with low temperatures do not. The derived temperature is weakly anticorrelated with luminosity and associated parameters, but there are no strong correlations with other parameters. Additional analysis and results will be discussed. This research is funded by NSF AST-0707703.

142.46

Kinematic Signatures of Seyfert AGN Fueling on Scales from 1 kpc to 10 pc

Erin K. Hicks¹, R. I. Davies², E. Emsellem³, W. Maciejewski⁴, M. A. Malkan⁵, T. Quinn¹ ¹University of Washington, ²Max Planck Institute, Germany, ³ESO, Germany, ⁴Liverpool John Moores University, United Kingdom, ⁵University of California, Los Angeles. Exhibit Hall

Aiming to constrain the dynamical processes that dictate black hole accretion rates in Seyfert galaxies, we have begun a program in which we simultaneously probe the stellar and molecular gas kinematics from 1 kpc down to ~10 pc in matched samples of Seyfert and quiescent galaxies. Using adaptive optics-assisted integral field K-band spectroscopy we identify differences in these samples including gas content within the central ~100 pc, prevalence of thick nuclear gas disks, significance of non-circular motions, frequency of central stellar dispersion drops indicative of past inflow of the interstellar medium, and characteristics of the nuclear star formation (rates and age of last episode). Preliminary results will also be presented from an ongoing effort to interpret the non-circular kinematic signatures observed in the molecular gas via theoretical dynamical models, which will enable us to determine the primary mechanisms responsible for Seyfert AGN fueling and assess their potential impact on galaxy evolution.

Time-Variability of the Circular Polarization From Active Galactic Nuclei At Multiple Frequencies Hugh D. Aller¹, M. Aller¹

¹Univ. of Michigan.

Exhibit Hall

We have monitored a group of bright AGN at 14.5, 8.0 and 4.8 GHz with the University of Michigan 26meter telescope to better define the variability of these active sources in Stokes V. The stability in the sign of the circular polarization has implications for the mechanism believed to be responsible for the emission: specifically tests of the proposed links between the Black Hole - accretion disk and the radio jet. The only source in which we find a stable sign over many years at all three frequencies is OV-236. This polarity is maintained throughout several outbursts in both linear and circular polarization. In other sources we typically find evidence for a preferred polarity for an extended period intermixed with welldefined flips in sign for durations of months to a few years. A good example of this behavior is exhibited by 3C 279. In several sources we also observe differences in polarity between the three frequencies at a single epoch. This work is supported by NSF grant AST-0607523.

142.48

SPH Simulations of Spherical Bondi Accretion: First Step of Implementing AGN Feedback in Galaxy Formation

Paramita Barai¹, D. Proga¹, K. Nagamine¹

¹University of Nevada, Las Vegas.

Exhibit Hall

Our motivation is to numerically test the assumption of Black Hole (BH) accretion (that the central massive BH of a galaxy accretes mass at the Bondi-Hoyle accretion rate, with ad-hoc choice of parameters), made in many previous galaxy formation studies including AGN feedback.

We perform simulations of a spherical distribution of gas, within the radius range 0.1 - 200 pc, accreting onto a central supermassive black hole (the Bondi problem), using the 3D Smoothed Particle Hydrodynamics code Gadget.

In our simulations we study the radial distribution of various gas properties (density, velocity, temperature, Mach number).

We compute the central mass inflow rate at the inner boundary (0.1 pc), and investigate how different gas properties (initial density and velocity profiles) and computational parameters (simulation outer boundary, particle number) affect the central inflow.

Radiative processes (namely heating by a central X-ray corona and gas cooling) have been included in our simulations.

We study the thermal history of accreting gas, and identify the contribution of radiative and adiabatic terms in shaping the gas properties.

We find that the current implementation of artificial viscosity in the Gadget code causes unwanted extra heating near the inner radius.

142.49

Comparing The Temporal Evolution Of NIR And Fermi/LAT Observations Of Blazars

Ori D. Fox¹, A. S. Kutyrev², J. T. Bonnell², J. P. Norris³, C. R. Klein⁴, J. S. Bloom⁵

¹NASA/GSFC/ORAU, ²NASA Goddard Space Flight Center, ³University of Denver, ⁴University of California, ⁵University of California, Berkeley.

Exhibit Hall

Over the past year, the Wyoming Infrared Observatory (WIRO) near-infrared (NIR) camera observed 50 blazars with known flaring states out to a redshift z=2. Data were obtained in conjunction with

previously scheduled Fermi/LAT observations over daily, weekly, and monthly time-scales. The Peters Automated Infraed Imaging Telescope (PAIRITEL) provided additional NIR observations. Here, we present a comparison of the fluxes and search for a correlation, or lack thereof, between the different wavelengths. We expect these results to have an impact on our understanding of the relationship between the temporal-spectral behavior of blazar physical states and the black hole evolutionary time scale.

142.50

Seeing Through the Clouds: AGN Geometry with the Swift BAT Sample

Eilat Glikman¹, M. Urry¹, K. Schawinski¹, M. J. Koss², L. M. Winter³, M. Elitzur⁴, W. H. Wilkin¹ ¹Yale University, ²University of Maryland, ³University of Colorado, ⁴University of Kentucky. Exhibit Hall

We investigate the intrinsic structure of the clouds surrounding AGN which give rise to their X-ray and optical emission properties. Using a complete sample of Swift BAT AGN selected in hard X-rays (14-195 keV), which is unbiased with respect to obscuration and extinction, we compute the reddening in the broad line region along the line of sight to the nucleus of each source using Balmer decrement from the ratio of the broad components of H-alpha/H-beta. We compare reddening from dust in the broad line clouds to the hydrogen column density (N_H) obtained from their X-ray spectra. The distribution of the gas-to-dust ratios over many lines of sight allow us to test models of AGN structure and probe the immediate environment of the accreting supermassive black holes.

142.51

Expanding a Monte Carlo Radiation Transfer Scheme to include Anisotropic Magnetic Fields and Bulk Velocities, and Applications to AGN's

Guy L. Hilburn¹, E. Liang¹

¹Rice University.

Exhibit Hall

To extend its usefulness to applications for AGN's, astrophysical jets, and other myriad sources, our Monte Carlo radiation transport has been modified in several important ways. Previously, magnetic fields were considered as having no angle dependence or "structure". Changes have made it possible to consider fields which point in any direction in each simulation cell, which will be vital for properly modelling AGN's, whose fields are strongly anisotropic. Similarly, other modifications have added the capability of treating the simulation plasma as having macroscopic flow. That is, the emission, scattering, and transport of photons in the volume is now dependent on the bulk motion of the plasma. This will be especially important when simulating jets, where speeds may be a considerable fraction of the speed of light.

142.52

Indecent Exposure in Seyfert 2 Galaxies: A Deeper Look Hien D. Tran¹

¹W.M. Keck Observatory.

Exhibit Hall

NGC 3147, NGC 4698 and 1ES 1927+654 are three Seyfert 2 galaxies with an unusual combination of properties: X-ray spectra show variability and little absorption indicative of a type-1 (direct) view, but optical spectra show only narrow emission lines, typical of a type-2 (obscured) view of the nucleus. A deep search for hidden broad-line regions (BLR) using Keck LRIS spectropolarimetry and direct near-IR spectroscopy with NIRSPEC does not reveal any broad emission lines, hidden or direct. If typical broad lines were present, the BLR non-detections would indicate an extinction of ~ 11 - 26 mag, inconsistent with their ``naked'' nature. While the obscuration may be due to different material for X-ray and optical

light, it appears that the BLRs in these objects are anemically small or nonexistent, due to the weakness of their active central engines.

142.53

Relativistic Hotspots in FR II Radio Sources

Alex M. Chartrand¹, B. P. Miller², W. N. Brandt³, M. P. Gawronski⁴, S. E. Cederbloom¹ ¹University of Mount Union, ²University of Michigan, ³Pennsylvania State University, ⁴Nicolaus Copernicus University, Poland.

Exhibit Hall

We present a list of six FR II radio sources that are candidates to possess hotspots with modestly relativistic (v/c > 0.2) bulk velocities, in contrast to the vast majority of FR II radio sources that possess non-relativistic hotspot bulk velocities (e.g., v/c = 0.03 + -0.02 from Scheuer 1995). These objects display arm- length and flux-ratio asymmetries between lobes that self-consistently indicate relativistic motion. The candidates are selected from the FIRST 1.4 GHz survey (including but not limited to the catalog of FR II quasars of de Vries et al. 2006) with the requirement that the radio core have a spectroscopic SDSS counterpart. We find no significant difference in the number of neighboring sources within 300 projected kpc of the candidate sources and randomly selected nearby regions. The deprojected and light travel-time corrected lobe distances are not abnormal for FR II sources, and neither are the core-to-lobe flux ratios after correcting for lobe beaming. We briefly consider four possibilities for these type of objects: (i) environmental interactions randomly mimicking relativistic effects, (ii) a restarted jet causing the near hotspot to brighten while the far hotspot still appears faint, (iii) observation during a short interval common to FR II lifetimes during which the hotspot decelerates from relativistic to non-relativistic velocities, and (iv) innately unusual characteristics (e.g., a massloaded jet) driving relativistic bulk velocities in the hotspots of a small fraction (< 1%) of FR II objects. We favor the last interpretation but cannot rule out the alternatives. We also comment on the useful external constraints such objects provide to the evaluation of hotspot X-ray emission mechanisms.

142.54

Broad Absorption Line Variability in Radio-Loud Quasars

Christine Welling¹, B. P. Miller², W. N. Brandt³, R. R. Gibson⁴, M. C. Eracleous³, K. T. Lewis⁵ ¹Dickinson College, ²University of Michigan, ³Pennsylvania State University, ⁴University of Washington, ⁵College of Wooster.

Exhibit Hall

We investigate broad absorption line (BAL) variability within a sample of 20 radio-loud quasars (RLQs) using Sloan Digital Sky Survey (SDSS) spectra along with new Hobby-Eberly Telescope (HET) observations. By comparison to BAL variability in radio-quiet quasars (RQQs), we aim to assess whether BAL outflows in RLQs have a similar physical origin to those in RQQs. The BAL RLQs were selected from SDSS/FIRST data and include both core-dominated (17) and lobe-dominated (3) objects; their radio luminosities and radio-loudness values span 2.5 and 3 orders of magnitude, respectively, and a substantial fraction have large BAL velocities (8/20 exceed 10000 km/s) and equivalent widths (6/20 exceed rest-frame 4000 km/s). Only modest BAL variability is detected on rest-frame timescales of 300-1000 days: the median fractional change in equivalent width is 0.07, exceeds 0.2 for only 3/20 objects, and in no cases is greater than 0.30. We do not find any correlation between the fractional change in equivalent width and radio luminosity. There is a possible tendency for lobe-dominated objects to display greater variability, but a larger sample is required for confirmation. Comparison to variability in BAL RQQs does not reveal significant differences in the distribution of fractional change in equivalent width. This suggests that the mechanism of BAL production within this sample of RLQs may be similar to that of the comparison BAL RQQs. We extend this comparison to shorter timescales (30-300 rest-frame

days) through the additional inclusion of BAL RLQs with multiple SDSS spectra, and discuss the results. Additional coverage at longer timescales would be helpful to investigate whether the variability amplitude increases for BAL RLQs, as it apparently does for BAL RQQs.

142.55

Multiwavelength Study of Gamma-Ray Bright Blazars

Daria Morozova¹, V. M. Larionov¹, V. A. Hagen-Thorn¹, S. G. Jorstad², A. P. Marscher², I. S. Troitskii¹ ¹St.Petersburg State Univ., Russian Federation, ²IAR, Boston Univ..

Exhibit Hall

We investigate total intensity radio images of 6 gamma-ray bright blazars (BL Lac, 3C 279, 3C 273, W Com, PKS 1510-089, and 3C 66A) and their optical and gamma-ray light curves to study connections between gamma-ray and optical brightness variations and changes in the parsec-scale radio structure. We use high-resolution maps obtained by the BU group at 43 GHz with the VLBA, optical light curves constructed by the St.Petersburg State U. (Russia) team using measurements with the 0.4 m telescope of St.Petersburg State U. (LX200) and the 0.7 m telescope of the Crimean Astrophysical Observatory (AZT-8), and gamma-ray light curves, which we have constructed with data provided by the Fermi Large Area Telescope. Over the period from August 2008 to November 2009, superluminal motion is found in all 6 objects with apparent speed ranging from 2c to 40c. The blazars with faster apparent speeds, 3C 273, 3C 279, PKS 1510-089, and 3C 66A, exhibit stronger variability of the gamma-ray emission. There is a tendency for sources with sharply peaked gamma-ray flares to have faster jet speed than sources with gamma-ray light curves with no sharp peaks. Gamma-ray light curves with sharply peaked gamma-ray flares possess a stronger gamma-ray/optical correlations.

The research at St.Petersburg State U. was funded by the Minister of Education and Science of the Russian Federation (state contract N#P123).

The research at BU was funded in part by NASA Fermi Guest Investigator grant NNX08AV65G and by NSF grant AST-0907893. The VLBA is an instrument of the National Radio Astronomy Observatory, a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

142.56

Starburst and AGN Indicators in Optically Faint X-ray Sources in the Cosmic Evolution Survey **Derek Robins**¹, M. Elvis², F. Civano²

¹Harvard College, ²Harvard-Smithsonian Center for Astrophysics. Exhibit Hall

A sample of 55 faint, X-ray selected objects were chosen for analysis from the COSMOS survey with high quality Keck DEIMOS data. The average redshift of the sample was 1.36, consistent with the average redshift of type 1 AGN in COSMOS of 1.4. Emission lines, NeV - an indicator of AGN luminosity - and OII an indicator of star formation rate, were measured for a subset of 34 objects. Line properties for these objects were measured. The combination of the two lines is evidence for significant star formation in these obscured AGN. Differences between OII and NeV redshifts were measured carefully. Significant differences between OII and NeV redshifts were found in 10-14 objects, implying OII outflows. The results are consistent with current models of galaxy evolution that invoke an interplay between AGN activity and star formation.

VLBI Images of Water Maser Galaxies

Caterina Impellizzeri¹, J. Braatz¹, C. Kuo¹, J. Condon¹, C. Henkel², M. Reid³, F. Lo¹ ¹NRAO, ²MPIfR, Germany, ³CfA.

Exhibit Hall

The goal of the Megamaser Cosmology Project (MCP) is to determine a precise value of the Hubble Constant by measuring angular diameter distances to galaxies in the Hubble flow using the megamaser technique. We search for new megamasers and monitor the most promising ones with the Green Bank Telescope. The best candidates are then followed up with high-resolution VLBI observations to map the maser distribution. These observations provide direct geometrical distances to the galaxies, precise black-hole masses, and offer the opportunity to study their physical properties on sub-parsec scales. We present here an atlas of all VLBI maps of megamaser galaxies observed to date by the MCP. The maser distribution in these galaxies is consistent with emission from edge-on accretion disks in the AGN. The variety of properties gives insight into the different physical conditions associated with accretion onto a black hole, and we discuss those implications here.

142.58

Double-peaked Narrow Emission Lines In AGN: Jets, Spins Or Twins?

Krista Smith¹, G. A. Shields¹, S. Salviander¹, D. J. Rosario²

¹University of Texas at Austin, ²Max Planck Inst., Germany. Exhibit Hall

AGN with double-peaked narrow lines have attracted recent attention as candidates for binary AGN in galaxy mergers. However, double-peaked lines can also result from bipolar jets or rotating disks. We examine tests of these possibilities involving the properties of the emission lines. Indicators based on the velocity separation of the components suggest that objects with equal intensity peaks may be rotating disks.

142.59

Properties Of Seyfert 2 Galaxies: Divergence From Unified Model?

Kazuyuki Tamura¹, H. Kim¹, M. J. Rutkowski¹, R. A. Windhorst¹

¹Arizona State Univ..

Exhibit Hall

At the nucleus of the Seyfert galaxies, broad-line region (BLR) is surrounded by the dust torus. According to the unified model of active galactic nucleus (AGN), different types of Seyfert galaxies are classified based on viewing angle of the AGN: signature of BLR is missing in Seyfert 2s due to obscuration by dust torus. However, recent studies find some differences between the properties of the two types of Seyferts that are inconsistent with simple unified model. Simulations show that BLR features can also disappear at very low accretion rates onto the central black hole. Such low accretion rates may be accompanied by declining star formation rates in the host galaxy. We investigated this possibility through a multi-wavelength study of 44 nearby Seyfert galaxies selected from the Palomar spectral survey, using data/images observed by Chandra, GALEX, XMM-Optical Monitor (XMM-OM), HST, 2MASS, and Spitzer (IRAC and MIPS). We compare the global star formation rates measured from the near ultraviolet (GALEX and/or XMM-OM) and Spitzer 24 micron images, and quantify the galaxies' structure in each band using variety of methods such as 2-D decomposition, CAS (Concentration, Asymmetry, and Clumpiness) and Gini parameters. Correlations between these different parameters, including the nuclear accretion rates, therefore, reveal whether Seyfert 2 galaxies are the results of the viewing angle (following unified model) of AGN, or whether some Seyfert 2 galaxies have mechanically different

properties from the others.

Funding for this project is provided through NASA/ADP grant NNX10AD77G.

142.60

Observations of Markarian 421 with the WIYN Telescope for a Multiwavelength Blazar Campaign David F. Fierroz¹, T. Montaruli²

¹Columbia University, ²University of Wisconsin-Madison.

Exhibit Hall

This is a report on the recent work of a long term multimessenger and multiwavelength campaign on blazars. We show how we have set up the tools to analyze the data of the WIYN 0.9m optical telescope during two periods in 2008-2009 and 2009-2010. We present the optical data we collected here as well as a preliminary correlation study. We are mostly interested in the variability in time of the optical emission in order to correlate to other wavelengths. The Whipple public data for the same periods are shown as an example of correlation studies in the TeV band and in the optical. This work was supported by the National Science Foundation's REU program through NSF Award AST-1004881

142.61

A New Analytical Model for Trans-Relativistic Particle Acceleration

Peter A. Becker¹

¹George Mason University.

Exhibit Hall

Most existing analytical models describing the second-order Fermi acceleration of relativistic particles due to collisions with MHD waves assume that the injected seed particles are already highly relativistic, despite the fact that the most prevalent source of particles is usually the local thermal background, which is typically a non-relativistic gas. This presents a problem because the momentum dependence of the momentum diffusion coefficient describing the interaction between the particles and the MHD waves is qualitatively different in the non-relativistic and highly relativistic limits. Since the existing analytical models are not able to address this situation, workers have had to rely on numerical simulations to obtain particle spectra describing the trans-relativistic case. In this work we present the first analytical solution to the global, trans-relativistic problem, obtained by using a hybrid form for the momentum diffusion coefficient, given by the sum of the two asymptotic forms. The model also incorporates the appropriate momentum dependence for the particle escape timescale, and the effect of synchrotron and inverse-Compton losses, which are critical for establishing the location of the high-energy cutoff in the particle spectrum. The results can be used to model the acceleration of particles in AGN and solar environments, and can also be used to compute the spectra of the associated synchrotron and inverse-Compton emission. Applications of both types are discussed.

142.62

Analysis of GALFACTS Data for the Study of Variable Radio Sources

Scott Barenfeld¹, T. Ghosh², C. Salter²

¹NAIC/University of Rochester, ²NAIC.

Exhibit Hall

The G-ALFA Continuum Transit Survey (GALFACTS) is a spectro-polarimetric survey of Arecibo Observatory's visible sky from 1225-1525 MHz, using the Arecibo L-band Feed Array (ALFA). Among the survey's many scientific goals is a large-scale statistical study on the short-term variability of the flux density and polarization of radio sources. Every point in the sky is observed twice, with less than a month between observations, making this the largest systematic search for variability ever conducted. In this poster, we present the development of computer code to aid in this search, and some preliminary results from this code. The code takes GALFACTS data in the form of time series for 2048 individual spectral channels, containing positions and full-stokes antenna temperatures, and turns these into a list of individual radio sources with their positions and Stokes-I temperatures. We first ran the code for the field surrounding the radio source S0206+330, of known flux density, as a test. Once a working code was completed, it was run on the field of another radio source, S0311+307.

142.63

A Difference-Imaging Survey for AGN in Stripe 82

Yumi Choi¹, R. R. Gibson¹, A. Becker¹, Z. Ivezic¹, A. J. Connolly¹ ¹University of Washington.

. Exhibit Hall

With upcoming surveys such as LSST poised to generate a deep movie of the optical/UV sky, variabilitybased selection promises to generate highly-complete AGN catalogs while minimizing contamination. To prepare for large time-domain surveys, photometric analyses are currently focusing on SDSS Stripe 82 because it covers a large area of sky (about 300 square degrees) with ~70 epochs of observations in each of five (ugriz) filters. We are exploring an alternate approach to variability-based selection in Stripe 82 data, using difference-imaging code developed for the LSST survey. Difference imaging analyses do not need to assume or fit a source model, so they excel at identifying variable sources embedded in complex or blended emission regions. Our initial goal in this project is to identify AGN that are surrounded by host-galaxy emission, including lower-luminosity AGN that may be omitted from photometric or spectroscopic catalogs. We describe algorithmic and computational challenges faced by such an analysis and compare our results to existing catalogs of Stripe 82 sources in order to determine the best strategies for distinguishing AGN from star-forming galaxies, quiescent galaxies, and other types of sources that can contaminate AGN catalogs.

142.64

Multi-waveband Variations of Blazars from Turbulent Plasmas Crossing Shock Waves Alan P. Marscher 1

¹Boston Univ..

Exhibit Hall

The author is developing a model in which much of the optical and high-energy radiation in a blazar is emitted near the 43 GHz core of the jet as seen in VLBA images, parsecs from the central engine. The main physical features are a turbulent ambient jet plasma that passes through either standing or moving shock waves in the jet. The model allows for short time-scales of optical and gamma-ray variability by restricting the highest-energy electrons radiating at these frequencies to a small fraction of the turbulent cells, perhaps those with a particular orientation of the magnetic field relative to the shock front. Because of this, the filling factor at high frequencies is relatively low, while that of the electrons radiating below about 10 THz is near unity. Such a model is consistent with the following observational trends: (1) red-noise power spectra of flux variations in blazars, (2) shorter time-scales of variability of flux and polarization at higher frequencies, (3) mean polarization levels as well as fractional deviations from the mean that are higher at optical than at lower frequencies, (4) apparent rotations in polarization position angle, and (5) breaks in the synchrotron spectrum by more than the radiative loss value of 0.5. The dependence of items 2-4 on frequency is directly related to the change in spectral index beyond the break, according to the model.

The model is being expanded to include high-energy radiation from inverse Compton scattering. The numerical calculation takes into account the light-travel times from cell to cell and from each cell to the observer. The presentation will include preliminary results of this added feature.

This research is supported in part by NASA through Fermi grants NNX08AV65G and NNX10AO59G, and by NSF grant AST-0907893.

142.65 Magnetic Fields in Blazar Jets: Radio and Optical Polarization over 20-30 Years Caroline Caldwell¹, B. Wills¹, D. Wills¹, H. Aller¹, M. Aller¹

¹University of Texas.

. Exhibit Hall

Blazars are highly active nuclei of distant galaxies. They produce synchrotron-emitting relativistic jets on scales of less than a parsec to many Kpc. When viewed head-on, as opposed to in the plane of the sky, the jet motion appears superluminal, and the emission is Doppler boosted. Blazars show rapid radio and optical variability in flux density and polarization. There are two types of blazars that can have strong synchrotron continua: non-BL Lac blazars with strong broad emission lines (quasars), and BL Lac objects with only weak lines.

We have compiled optical linear polarization measurements of 22 blazars, incorporating much archival data from McDonald Observatory. While the optical data are somewhat sparsely sampled, The University of Michigan Radio Astronomical Observatory observed many blazars over 20-30 years, often well-sampled over days to weeks. These data enabled us to compare optical and radio polarization position angles. We constructed histograms of the separation of polarization position angles of the optical and radio. We found that in BL Lac objects, the histogram has a significant peak at zero separation. Since the polarization position angle indicates the direction perpendicular to the magnetic field vector, finding similar polarization position angles indicates a similar magnetic field at the origin of the optical and radio synchrotron radiation. Non-BL Lac blazars show peaks at zero and 90 degree separation of position angle. The 90 degree separation may be caused by optical depth effects within the jet. Although there are a few sources that do not strongly display the characteristics summarized by the histograms, most sources produce optical and radio polarization position angles that nearly coincide or are separated by 90 degrees. Using VLBA and VLA radio maps, we interpret the results in terms of the position angle of the jet in the sky plane.

143 *Black Holes* Poster Session *Exhibit Hall*

143.01

Time-Variable Compact Emission Around the Galactic Center Black Hole Vincent L. Fish¹, S. S. Doeleman¹, EHT Collaboration ¹*MIT Haystack Observatory. Exhibit Hall*

The Galactic Center radio source Sagittarius A* is believed to host a massive black hole. The event horizon of Sgr A* subtends a larger angle than any other known black hole candidate. The resolution of millimeter-wavelength very long baseline interferometry (VLBI) is perfectly suited to studying Sagittarius A*. In prior observations, our collaboration detected Sagittarius A* at 1.3 mm wavelength on a baseline between the James Clerk Maxwell Telescope (JCMT) in Hawaii and the Submillimeter Telescope (SMT) in Arizona, demonstrating the existence of structure on the scale of a few Schwarzschild radii. We report on new 1.3 mm VLBI observations of Sagittarius A* using an array consisting of the JCMT, the SMT, and two telescopes of the Combined Array for Research in Millimeter-wave Astronomy (CARMA) in California. For the first time, we detect Sgr A* on JCMT-CARMA baselines. The data indicate that Sagittarius A* is composed of both a 43 microarcsecond (4.3 Schwarzschild radii) compact component as well as a large-scale component (> 300 microarcseconds) that is resolved out on VLBI baselines. The flux density of the compact component is seen to increase on one day, but the implied size of the emission

region remains constant. These result place strong constraints on the quiescent and flaring emission mechanisms of Sgr A*.

High-frequency VLBI work is supported by grants from the National Science Foundation.

143.02

Ultraluminous X-ray sources in Interacting Arp Galaxies

Douglas A. Swartz¹, A. F. Tennant², R. Soria³

¹USRA/MSFC, ²NASA/MSFC, ³MSSL/UCL, United Kingdom.

Exhibit Hall

Chandra X-ray Observatory spectrophotometric images of interacting galaxies in Arp's Atlas of Peculiar Galaxies are used in a search for Ultraluminous X-ray sources (ULXs). The resulting population census is compared to that of spiral and elliptical galaxies in order to test the hypothesis that ULXs occur more frequently in interacting and in starburst galaxies compared to the normal galaxy population. An interesting number of ULXs are found along tidal tails and bridges suggesting X-ray binary formation is somehow especially favored in these environments.

143.03

Fingerprints of Intermediate Mass Black Holes in Globular Clusters Michele ${\rm Trenti}^1$

¹University of Colorado.

Exhibit Hall

Globular clusters seem to be the best place to search for Intermediate Mass Black Holes (IMBHs) in the local universe, but so far no definitive observational evidence for their existence has been found. Here we evaluate the uniqueness of classical signatures from stellar dynamics that are typically associated to the presence of a central IMBH (shallow cusp in the surface brightness profile and central rise in the velocity dispersion). We also present a novel technique to identify likely IMBH hosts, based on the measurement of mass segregation in collisionally relaxed globular clusters.

143.04

A Refined Black Hole Mass for the X-ray Transient GRS 1009-45

Phillip Macias¹, J. A. Orosz², C. D. Bailyn³, M. M. Buxton³, P. L. Schechter⁴, R. A. Remillard⁴, J. E. McClintock⁵, J. F. Steiner⁵

¹University of California, Santa Barbara, ²San Diego State University, ³Yale University, ⁴Massachusetts Institute of Technology, ⁵Harvard/Smithsonian Center for Astrophysics. Exhibit Hall

We have acquired new spectroscopic and photometric observations of the black hole binary GRS 1009-45. The source was observed using the MagE spectrograph on the 6.5m Magellan Clay Telescope at Las Campanas Observatory in February, 2008. A total of 11 useful spectra with a resolving power of 4000 were obtained. The source was monitored by the 1.3m SMARTS telescope at Cerro Tololo Observatory between December, 2007 and June, 2010. In total we obtained 342 useful images in R and 119 images in J. Additional J- and Ks-band images were obtained using the PANIC camera on the Magellan Baade Telescope April, 2008. From the spectra we were able to measure (for the first time) the rotational velocity of the K-star companion. The projected rotational velocity of 86.8 +\- 5.2 km/sec implies a mass ratio of M/M_2 of about 17. The spectra also imply an R-band disk fraction of about 30%. The SMARTS light curves show evidence for a strong asymmetry that changes slowly with time. Previously published light curves obtained in runs of a few nights also show an asymmetry. This feature was modeled using a bright spot on the accretion disk. Using all of the available light curves we find an inclination near 50 degrees, and component masses of about 8.5 and 0.5 solar masses for the black hole and companion star, respectively. P. M. acknowledges support from the NSF REU program at San Diego State University that is supported by grant AST-0850564.

144

Binary Stellar Systems, X-ray Binaries Poster Session *Exhibit Hall*

144.01

Get a Clue with ZZ Boo

Brian Kirk¹, A. Prsa¹, S. Engle¹, J. Robertson¹ ¹*Villanova University.*

Exhibit Hall

ZZ Bootis is a detached eclipsing binary that has been the subject of spectroscopic analysis before, yet these data were acquired in 1950s and the early 1960s, which prompted us to further study this system. Earlier this year, we acquired spectroscopic data from a 2.1m telescope at Kitt Peak National Optical Astronomy Observatory of ZZ Boo at eighteen different phases. The parameters deduced from eclipsing binaries are used to calibrate our current evolutionary models. These observations give physical confirmation of our theories and allow us to calibrate the mass-luminosity relationship from which the masses of single stars can be estimated. Because a large proportion of stars exists in binary systems, binaries are particularly important to our understanding of the processes by which stars form. Furthermore it has been demonstrated that eclipsing binaries are excellent distance indicators, permitting the calibration of the cosmic distance scale essentially free from assumptions. We prepare the data for study by performing cosmic ray removal, wavelength calibration, and flux normalization for cross-correlations to extract radial velocities. After the reduction process, we use PHOEBE to simultaneously model light curves, radial velocity curves, and spectra of ZZ Boo. We present our current findings on our poster. We gratefully acknowledge grant NSF/RUI grant AST-05-07542.

144.02

The Spectroscopic and Photometric Analysis of the Eclipsing Binary System DN UMa

Jordan Robertson¹, A. Prsa¹, B. Kirk¹, S. Engle¹

¹Villanova University.

Exhibit Hall

The eclipsing binary system DN UMa (HD 103483) is a likely triple system with a possible pulsating component that has been studied extensively. The period of ~1.7-d has been determined by Gimenez and Queseda (1982). Wilson (1953) reported a systemic radial velocity of -8 km/s, based on a limited data-set. To investigate this interesting object further, we initiated a photometric campaign in April 2009 on the Automatic Photoelectric Telescope in Patagonia, AZ. In January 2010 we followed up DN UMa spectroscopically at the 2.1 m telescope at Kitt Peak National Observatory. The high-resolution echelle spectra have been processed in IRAF. The exposures have been cleaned of cosmic rays, and the extracted spectra have been wavelength-calibrated and flux-normalized. In conjunction with photometry, the spectroscopic data were used to determine fundamental parameters (radii, masses, and temperatures) of the binary star components. We present the results of the modeling based on archival and newly acquired data.

144.03 Solving the Mysteries of Potential Eclipsing Binaries NSV 860 and V795 Cas Emily Rosche¹, A. Prsa¹, J. Robertson¹, B. Kirk¹

¹Villanova University.

Exhibit Hall

NSV 860 was classified as an eclipsing binary in 1936 by Zinner but has been neglected since. V795 Cas has also been classified as an eclipsing binary system in the SIMBAD database, however no definitive studies have been done on either one in order to confirm this, so they both seemed objects worthy of further study. Consequently, we have obtained 18 spectra of NSV 860 and 14 spectra of V795 Cas in order to determine the true nature of these systems. Using IRAF software we removed the systematic artifacts and cosmic rays from the data and then proceeded to wavelength-calibrate the spectra. From here we analyzed the spectra in order to accurately and scientifically classify the star systems. We gratefully acknowledge NSF/RUI grant AST-05-07542 and the VURF grant given by Villanova University.

144.04

Analysis and Modeling of Eclipsing Binary AI Hydrae

Cindy Villamil¹, A. Prsa¹, S. G. Engle¹, B. M. Kirk¹, J. A. Robertson¹

¹Villanova University.

Exhibit Hall

AI Hydrae is an F-type detached eclipsing binary that we know a considerable amount about. In 1988, Popper analyzed light curves and spectra of AI Hydrae to determine parameters such as the spectral type, period, orbital eccentricity, systemic velocity, and argument of periastron. We have retaken photometry of the system using the Four College Automated Photoelectric Telescope and acquired echelle spectra with the 2.1 and 4 meter telescopes at Kitt Peak National Observatory, both located in Arizona. We reduced the echelle spectra using IRAF to remove the cosmic rays in the data, perform wavelength calibration, and measure the Doppler shifts of the spectral lines to obtain radial velocity curves. After reducing the spectroscopic data we simultaneously analyzed the radial velocities with the light curves for AI Hydrae to compare those results with the previous values from the literature. With this analysis, we aim to reduce the error margin of the system's physical parameters such as masses, luminosities, radii, and velocities, and consequently, further calibrate the mass-luminosity relationship. This poster presents preliminary results of our analysis and modeling based on our acquired data. We gratefully acknowledge NSF/RUI grant AST-05-07542.

144.05

Spectral Analysis of the Mass Flow in Binary System U Cephei

Peter R. Tupa¹, G. G. DeLeo¹, G. E. McCluskey, Jr.¹

¹Lehigh University.

Exhibit Hall

Data from the International Ultraviolet Explorer (IUE) archive was utilized in the analysis of the Algol type eclipsing binary star system U Cephei (HD 5679). The U Cep system consists of a B7V primary star and G8IV secondary that is actively transferring mass to the primary. A total of 115 spectral images from the IUE archive were analyzed, with special attention given to the 29 images taken during a complete period of 2.5 days. Synthetic spectra generated via TLUSTY and SYNSPEC were used, along with comparison spectra from the standard star Regulus, to determine continuum flux levels, light curves, and radial velocities for the system. Observations of non-photospheric absorption features suggest a transient outward matter flow present in the early observed phases of 0.48 to 0.69, but the same features are significantly reduced in the same phases one period later. Additionally, simulated spectra

suggest absorption features previously thought to be high energy Si IV and C IV lines may in fact be anomalous convolutions of different ionic species at lower temperatures.

144.06

CCD Photometric Study of a Rare Algol Dwarf Binary System, V1001 Cassiopeiae

Heather Chamberlain¹, R. G. Samec¹, D. Faulkner², W. VanHamme³

¹Bob Jones University, ²University of South Carolina, Lancaster, ³Florida International University. Exhibit Hall

We present a photometric study of detached Algol system, V1001 Cas [RA(J2000) = 23h 50m 17.12 s, Dec(J2000)= +51° 11' 29", MisV1222, GSC 3651-00655, USNO-A2.0 1350.18742581] with 0.43 days period. It was discovered 2005 and reported in IBVS 5600 (Nakajima, Yoshida, and Ohkura 2005). Their report characterizes it as EB system. Its short period, similar to W UMa's and its distinct EA light curve (large eclipse depths difference, shallow amplitude secondary, long stretches of low variation outside eclipses) make it rare and interesting for photometric investigation. Our images were taken 26,27, September, 2009, at Lowell Observatory (NURO) and 28 September 2009 via remote observing from Kitt Peak with SARA. UBVRI CCD photometry shows V1001 Cas has a V=1.2 mag primary eclipse and a 0.1 mag secondary amplitude. Our period study yielded 5 times of minimum light. These include JD Hel Min II = 2455100.8306 \pm 0.0005, 2455101.6888 \pm 0.0002, 2455103.83367 \pm 0.00028 , JD Hel Min II = 2455100.6160 \pm 0.0005, 2455103.61961 \pm 0.0005.

Using CCD minima, we calculated the first precision ephemeris,

HJD Min I = 2455101.6890 ± 0.0008 + 0. 4287188 ±0.0000002d*E.

We first manually fit BVRI Johnson-Cousin's Photometry with Binary Maker. This revealed V1001 Cas is a well detached binary with spot activity. Next, we performed BVRI simultaneous WD synthetic light curve analysis. With its deeper secondary, the I curve, although of good quality, would not fit with the others. So, we did a BVR solution. Our first solution gives a mass ratio of nearly 1.0, a temperature difference of 850 K, with fill-outs of 71% and 78% of the primary and secondary stars' respective lobes. We only needed one 220 radius cool spot with a temperature of 0.72 times that of the photosphere. The stars appear to be of mid K and early M main sequence-type.

144.07

The Overcontact Binary V535 Aurigae: Well On Its Way to Coalescing?

David H. Bradstreet¹, S. J. Sanders¹, B. Hiebert-Crape¹

¹Eastern Univ..

Exhibit Hall

V535 Aurigae is a faint (12.8 mag) short period (9.23 hours) overcontact binary which has only one published light curve and no published analysis. 811 digital images in the V filter and 845 in R were obtained over seven nights in the winter of 2008 at the Bradstreet Observatory at Eastern University. The data were obtained using the Observatory's 41-cm telescope coupled with an SBIG ST-10XME CCD camera. Six new timings of minimum light were measured in order to analyze whether or not the system's period has changed since its discovery. Preliminary results tentatively indicated that the period had been decreasing linearly over the previous nine years since it was discovered. In order to confirm the large change in period the binary was observed in 2009 and 2010 resulting in complete V and R light curves in both seasons and an additional nine timings of minimum light. These timings confirm that V535 Aur has a dP/dt = -0.208 sec/yr, some twenty times greater than the average period change for overcontact systems. V535 Aur thus displays the largest decrease in period for any known overcontact system. The light curves were compiled into phased normal points and analyzed using the Binary Maker 3.0 light curve analysis software. These preliminary results were then fine tuned using the benchmark Wilson-Devinney code as implemented in Andrej Prsa's PHOEBE software suite. The analysis shows that

the system is totally-eclipsing with a fillout of 85% and equal component temperatures. The extraordinarily large fillout (average for overcontacts ~ 28%), equal stellar temperatures and very large period decrease may indicate that V535 Aur is well on its way to coalescing into a single star. The methods and results of the data acquisition, period study and light curve analysis will be presented in this poster.

144.08

Very Wide Binaries

Robert Olling¹, E. Shaya¹

¹Univ. Of Maryland.

Exhibit Hall

We develop Bayesian statistical methods for discovering and assigning probabilities to physical stellar companions. The probabilities depend on similarities in "corrected" proper motion, parallax, and the phase-space density of field stars.

Very wide binaries with separations over 10,000 AU have recently been predicted to form during the dissolution process of low-mass star clusters. In this case, these wide systems would still carry information about the density and size of the star cluster in which they formed.

Alternatively, Galactic tides and weak interactions with passing stars peel off stars from such very wide binaries in less than 1/2 of a Hubble time. In the past, these systems have been used to rule in/out MACHOs or less compact dark (matter) objects.

Ours is the first all-sky survey to locate escaped companions that are still drifting along with each other, long after their binary bond has been broken. We test stars for companionship up to an apparent separation of ~8 parsec: 10 to 100 times wider than previous searches.

Among Hipparcos stars within 100 pc, we find about 260 systems with separations between 0.01 and 1 pc, and another 190 with separation from 1 to 8 parsec.

We find a number of previously unnoticed naked-eye companions, among which: Capella & 50 Per; Alioth, Megrez & Alcor; gamma & tau Cen; phi Eri & eta Hor; 62 & 63 Cnc; gamma & tau Per; zeta & delta Hya; beta⁰¹, beta⁰² & beta⁰³ Tuc; 44 & 58 Oph and pi & rho Cep. At least 15 of our candidates are exoplanet host stars.

144.09

Standardization of Comparison Stars in the Fields of 10 High Mass X-ray Binaries Eric G. Hintz¹, M. D. Joner¹

¹Brigham Young Univ..

Exhibit Hall

To support our current observing program to monitor High Mass X-ray Binary (HMXB) systems for optical variability, we calibrated a large sample of comparison stars in the fields of ten HMXB systems. This was done using the new BYU West Mountain 0.9-m telescope. Calibrations were done in the B, V, and I filter with Landolt standard fields. Two of our systems, 4U 1907+09 and KS 1947+300, had previously published magnitudes for the optical counterpart of each x-ray system. The eight remaining systems had no identified optical counterparts. These systems include: AXJ1844.8-0258, 4U 1850-03, 4U 1901+03, 4U 1908+075, XTE J1906+090, XTE J1908+094, IGR J19140+0951, and IGR 18410-0535. We will report on the calibrations for each field and an attempt to identify each optical counterpart. This work is supported by NSF grants AST-0618209. We also acknowledge support from a BYU ORCA MEG grant.

144.10 Potential Optical Counterparts to High Mass X-Ray and γ -Ray Binaries Carl Mitchell¹, M. V. McSwain¹

¹Lehigh University.

Exhibit Hall

We seek to identify optical counterparts to several previously discovered high mass X-ray binaries and γ -ray sources from the Liu et al. and Fermi first year catalogues. Observations were taken with the CTIO 0.9-meter telescope, operated by the SMARTS Consortium. Photometric data were taken in the Strömgren b and y filters, as well as a narrow-band H α filter. We present color-color diagrams of y-H α vs. b-y for each field, and candidates for optical counterparts were selected based on their excesses of H α emission. We also present spectral energy distributions for select candidates. This work is supported by the NSF REU site grant PHY-0849416, NASA DPR No. NNX09AT67G, and Lehigh University. We also thank the SMARTS Consortium, Rachael Roettenbacher, Tina Aragona, and Amber Marsh.

144.11

Time-series, Multi-wavelength Monitoring Of The High Mass X-ray Binary 4U 2206+54

Jessica L. Bugno¹, E. G. Hintz¹, M. D. Joner¹, C. D. Laney¹

¹Brigham Young University.

Exhibit Hall

The high mass X-ray binary 4U 2206+54 has been a very controversial system. Optical time-series observations of this system from West Mountain Observatory and the Orson Pratt Observatory were analyzed to determine a more accurate orbital period. The summers of 2008 and 2009 provided a total of 55 nights of observations in the Johnson *V* filter. The summer of 2010 provided 20 nights of observations in Johnson *BVRI*. We present our preliminary results as of October 1, 2010 as well as the error analysis for the data. We also acknowledge NSF grant AST-0618209 for data collected from the West Mountain 36" telescope.

144.12

Optical Monitoring Of Two High Mass X-ray Binary Systems: 4u 1907+09 And Ks 1947+300 Juan C. Payan¹, E. G. Hintz², M. D. Joner²

¹Worcester Polytechnic Institute, ²Brigham Young University. Exhibit Hall

Using the BYU West Mountain 0.9-m telescope we monitored two High Mass X-ray Binary systems during the summer of 2010. The optical counterpart for 4U 1907+09 is reported as an O9 Ia star with an orbital period of 8.38 days and a magnitude of V= 16.4. For KS 1947+300 we find a B0 Ve reported as the optical counterpart with an orbital period of 40.4 days and V=14.2. We felt these two targets provided a good test of the new telescope's capabilities. Each target was observed every clear night from June to September in the broadband B, V, and I filter. We will report on the optical variability seen in both systems and its relation to the published periods. This work is supported by NSF grant AST-0618209.

144.13

Optical Monitoring Of Three High Mass X-ray Binary Systems: BD+53 2262, RX J2030.5+4751, And BD+49 3718

Nathaly Zurita¹, E. G. Hintz¹, E. Salway¹, C. R. Porritt¹

¹Brigham Young University.

Exhibit Hall

Over the past four summers we have monitored a number of High Mass X-ray binary systems as part of our undergraduate research program, including our REU program. These systems have been primarily monitored using the 0.4-m telescope of the BYU Orson Pratt Observatory. The data set is a mixture of

high density single night observing runs that cover many hours, along with long term night to night monitoring. In this poster we will present preliminary results for three systems we have monitored; BD+53 2262, RX J2030.5+4751, and BD+49 3718. We wish to acknowledge the support of a BYU ORCA MEGs grant which has provided support for this program.

144.14

CCD Photometry Of The Extreme Mass Ratio Binary, TYC 1404-1687-1

Danny R. Faulkner¹, Ron Samec, Evan Figg, Bruce Oliver, Astronomy Program, Bob Jones University, Walter VanHamme, Florida Interational University

¹University of South Carolina Lancaster.

Exhibit Hall

We report our photometric analysis of the variable, TYC 1404-1687-1 (GSC 1404 1687, Cancer). The images were taken in December, 2008, March 2009 with NURO and 16 January 2009 via remote observing with SARA North. The UBVRI CCD photometry shows that TYC 1404-1687-1 has a totally eclipsing W UMa light curve, yet it has a shallow amplitude (A_V ~0.4 mag.). We studied the possibility the low amplitude was due to the presence of a third component: we began our analysis with ~30% third light as determined from Binary Maker. Next, we performed a BVRI simultaneous WD synthetic light curve analysis. Surprisingly, we obtained two nearly identical sums of square solutions, one with a measurable but small third light component (0-2%) and another with no third light. We conclude that the solution does not require a third light.

Our period study yielded 9 new times of minimum light, two from ROTSEI curves, JD Hel Min= 2452721.4226 and 2452728.3972, and the others from our observations: HJD Min I = 2454848.8844 ±0.0014, 2454901.8924 ±0.0006, 2454902.6903 ±0.0014, 2454904.6790 ±0.0058, HJD Min II = 2454823.9678 ±0.0017, 2454827.9618 ±0.0005, 2454901.6927 ±0.0005. Using these, we calculated the first precision ephemeris for this system,

HJD Min I = 2454902.6912 ±0.0009 + 0.3985874 ±0.0000003 d*E.

UBVR_{clc} standard magnitudes were determined. We find that the comparison star (GSC 1404 0119) is a late G-type dwarf while the check star (GSC 1404 0587) is a mid F-type dwarf. The binary is an FOV contact binary. We also performed a number of solutions (a q-search) which minimized at a mass ratio near 0.2. Our WD solution gave a fill-out of 45%. No spots are needed in the solution. So we find that TYC 1404-1687-1 is among the once rare, but growing number, of low amplitude-extreme mass ratio, totally eclipsing binaries.

144.15

The Mass Transfer Rate Of A Nearly Semi-detached Eccentric Binary Star Systems

Colby Haggerty¹, J. F. Sepinsky¹

¹University of Scranton.

Exhibit Hall

We calculate the instantaneous mass loss rate of a nearly-semi-detached donor star in an eccentric orbit about its companion by taking into account the varying size and shape of the donor's Roche Lobe throughout the orbit. As in the circular case, we model the density of the stellar atmosphere as a decreasing exponential function of the instantaneous gravitational potential above the photosphere. At each point in the orbit, the equipotential surfaces corresponding to the stellar photosphere and the inner Lagrangian point need to be recalculated due to the changing distance between and relative orbital velocity of the two objects. By analyzing the shape of the potential in the vicinity of the inner Lagrangian point we can determine the effective cross-section of the flow out of the donor star's effective Roche Lobe. Combining this with mass density and sound speed we determine the instantaneous mass loss rate through the inner Lagrangian point of the donor star at each point in the orbit. We show the functional form of this rate over the course of a single orbit for a wide variety of binary parameters. This orbit variable mass loss rate is vital to proper calculations of orbital evolution of mass transferring eccentric binary system.

144.16

Estimating the Fraction of Binaries Affecting the JMAPS Astrometry

Henrique R. Schmitt¹, B. F. Lane², R. B. Hindsley³

¹NRL/CPI, ²C. S. Draper Laboratory, ³NRL.

Exhibit Hall

We estimate the fraction of stars that are binaries and have a large enough motion of the center of light relative to the center of mass of the system, larger than 1 mas, to significantly affect the astrometric accuracy of the Joint Milli-Arcsecond Pathfinder Survey (JMAPS). These calculations were done using information about the observed distribution of spectral types, the frequency of binary systems as a function of spectral type, their mass ratios and period distributions. We find that, for systems with periods smaller than 10 years, approximately 12 percent of the stars with I=2 mag will have a motion of the center of light relative to the center of mass larger than 1 mas, decreasing to less than 1 percent for stars with I=14 mag. We explore the effects of reddening, orbital eccentricity, and different distributions of spectral types, to these fractions. These results are compared with the fraction of binary stars detected by the Hipparcos satellite.

144.17

Exploring Possible Origins of an Improbable Binary Star in the Open Cluster NGC 6819 Through Dynamical Exchange Simulations

Thomas Finzell¹, A. Geller², N. Gosnell¹, R. Mathieu¹

¹UW Madison, ²Northwestern University.

Exhibit Hall

We model the origin of the binary star system, NGC 6819-3002-a highly improbable star system that is likely the remnant of a dynamical encounter. The horizontal-branch primary star would have had a large enough radius while in it's giant phase to engulf the orbit of the secondary star, making it very unlikely that these two stars were born together. In order to explore the likelihood that the binary was created via a dynamical exchange interaction we use a scattering experiment algorithm to simulate encounters between a single star and binary system. We use this to investigate the possible initial parameters that could produce the currently observed properties of the system. We incorporate the scattering experiments within a genetic algorithm, which searches over the large parameter space and iteratively selects initial parameters that yield the observed binary. The genetic algorithm gives us the ability to confine the potential parameter space into one of a computationally manageable size. We then perform a more systematic search of the identified region of parameter space in order

to determine the multi-dimensional probability distribution of parameters that can produce NGC 6819-3002. We then correlate that probability distribution with the distribution of binary and stellar parameters of NGC 6819 in order to determine the likelihood that such a dynamical interaction could have occurred. The result of this process shows that NGC 6819-3002 may indeed have originated through a dynamical exchange interaction. Applying this technique to additional stars and star systems in other clusters will allow us to constrain the impact of dynamical encounters on the formation of anomalous objects like NGC 6819-3002.

We gratefully acknowledge funding from the National Science Foundation under grant AST-0908082.

Comparisons Between SPH and Grid-Based Simulations of the Common Envelope Phase

Jean-Claude Passy¹, C. L. Fryer², S. Diehl², O. De Marco³, M. Mac Low⁴, F. Herwig⁵, J. S. Oishi⁶ ¹American Museum of Natural History and University of Victoria, ²Los Alamos National Laboratory, ³Macquarie University, Australia, ⁴American Museum of Natural History, ⁵University of Victoria, Canada, ⁶Kavli Institute for Particle Astrophysics and Cosmology.

Exhibit Hall

The common envelope (CE) interaction between a giant star and a lower-mass companion provides a formation channel leading eventually to Type Ia supernovae, sdB stars and bipolar PNe. More broadly, it is an essential ingredient for any population synthesis study including binaries, e.g. cataclysmic variables. Occurring on a short time scale - typically between one and ten years, the CE interaction itself has so far never been observed with certainty but the existence of companions in close orbits around evolved stars, whose precursor's radius was larger than today's orbital separation, vouches for such interaction taking place frequently. Via a detailed study of the energetics and the use of stellar evolution models, we derived in our previous paper the efficiency α of the CE interaction from a carefully selected and statistically analyzed sample of systems thought to be outcomes of a CE interaction. We deduced the initial configuration of those systems using stellar models, and derived a possible inverse dependence of α with the companion to primary mass ratio. Here, we compare these predictions to numerical simulations with two different codes. Enzo is a 3D adaptive mesh refinement grid-based code. For our stellar problem we have modified the way gravity and boundary conditions are treated in this code. The SNSPH code is a 3D hydrodynamics SPH code using tree gravity. The results from both codes for different companion masses and different types of primary stars are consistent with each other. Those results include a resolution study of a 0.88 M_{\odot} red giant interacting with a 0.9, 0.6 and 0.3 M_{\odot} white dwarf, respectively. Those systems reach a final separation of 25, 18 and 10 R_{\odot} , respectively. In this contribution, we present and discuss those results and compare them to our predictions. This research was funded by NSF grant 0607111.

144.19

The Colliding Stellar Winds of the Extreme Wolf-Rayet Binary CQ Cephei

Rosina Iping¹, G. Sonneborn¹, J. C. Bouret²

¹NASA's GSFC, ²Laboratoire d'Astrophysique de Marseille, France. Exhibit Hall

We present time-resolved observations of the Wolf-Rayet + O star Binary CQ Cephei using the FUSE satellite. We acquired a series of observations of CQ Cephei and determined the structure of the bow shock zone formed when the winds of the two hot stars collide. CQ Cephei has the shortest period of all the known W-R+O binaries. The W-R star is classified as a nitrogen-rich WN6 star and the companion as an O9 II-Ib star. The observations cover a significant part of the 1.64-day orbital period. We were able to study the wind interaction zone from phase-dependent spectral variations. Of particular importance in the FUSE wavelength range is the large number of emission lines of abundant elements with different ionization potentials, ranging from O VI, S IV, P V, C III, to N II. The S and P lines are important because these elements are produced only in SN explosions and are not enhanced by nuclear processes in the binary stars themselves. We present improved constraints on orbital parameters and on characteristics of the W-R star itself (wind momentum, mass-loss rate, and abundances).

144.20 Mass of the Black Hole in V4641 Sgr Rachel K. D. MacDonald¹, C. D. Bailyn¹, A. G. Cantrell¹

¹Yale University. Exhibit Hall

V4641 Sgr is a galactic microquasar, or x-ray binary, with a B9III star as secondary and an orbital period of 2.82 days. Although the secondary star is very bright (13th mag.), it is clear that the disk around the black hole also contributes to the optical emission. This makes the determination of the orbital inclination, and thus the mass of the compact object, uncertain. We present simultaneous spectroscopy and photometry from 2009 and 2010, taken at the SMARTS telescopes in Cerro Tololo, Chile, which enables us to determine the disk fraction of the optical emission. Once this disk fraction has been determined, a more definitive mass measurement for the black hole in the system will be possible.

144.21

Photometry, Spectroscopy, And Doppler Tomography Of The Eclipsing LMXB EXO 0748-676 = UY Vol Valerie J. Mikles¹, R. I. Hynes¹, E. D. Jones¹

¹Louisiana State University.

Exhibit Hall

We present optical spectra and Doppler tomography of the low-mass X-ray binary EXO 0748-676 = UY Vol. UY Vol is an eclipsing X-ray binary hosting a neutron star. With a total of 65 spectra spread over 4 nights, we have complete phase coverage and construct trailed spectra and Doppler tomograms for thirteen lines and line blends. Although we were not able to detect fluorescent N III/C III emission from the irradiated secondary, we do detect S-wave emission of several He II lines and O II 5289A. Our analysis of the trailed spectra and tomograms allows us to constrain the origin of the line emission. UY Vol has spent the better part of the last two decades in a burst state, but since our spectroscopy, the source has entered a quiescent phase. The optical counterpart, originally ~17th mag has faded substantially to R~22 mag. We present a new light-curve of the source in its quiescent state. This work is partially supported by the National Science Foundation under Grant No. AST-0908789 and by NASA/Louisiana Board of Regents grant NNX07AT62A/LEQSF(2007-10) Phase3-02.

144.22

New Low-Mass PMS Eclipsing Binaries In Orion

Maria Morales-Calderon¹, J. R. Stauffer¹, L. M. Rebull¹

¹IPAC-CALTECH.

Exhibit Hall

In Fall 2009, we conducted a large, multi-wavelength time-series photometric monitoring campaign of about a one square degree region of the Orion Nebula cluster (ONC). Our program produced light curves for 2000 Orion young stellar objects (YSOs), with data often in at least four bands (I, J, [3.6] and [4.5]). While our primary goal was to use these data to investigate the structure of the inner disk and time-variable accretion in YSOs with circumstellar disks, these data also provide a treasury of data on all types of pre-main-sequence (PMS) variability. Specifically, we identify nine stars in our FOV whose light curves show eclipse features. Four of these are the previously known ONC eclipsing binaries (EBs) and the other five systems are newly identified ONC PMS EB candidates - more than doubling what was known up to now. Here we present our current work to confirm these candidates.

Characterizing X-ray Point Source Populations in Nearby Galaxies

Tyler D. Desjardins¹, R. E. Kilgard¹, A. H. Prestwich²

¹Wesleyan University, ²Harvard-Smithsonian Center for Astrophysics.

Exhibit Hall

We present an analysis of Hubble Space Telescope ACS images of the nearby galaxies IC 10 and M 51 in which we determine the characteristics of optical sources that are coincident with X-ray point sources detected with the Chandra X-ray Observatory. For IC 10, we find optical counterparts for six sources consistent with B dwarf stars, with one of the sources likely coincident with an OB association. In M 51, there are twelve X-ray sources that have stellar counterparts with colors and magnitudes indicating O and B dwarfs as well as several early type supergiants. H-alpha images show several supernova remnants in M 51 that are coincident with X-ray point sources. We also present preliminary results on constructing discrete X-ray source luminosity functions segregated by class of optical counterpart.

144.24

The Chandra Galactic Bulge Survey

Robert I. Hynes¹, P. G. Jonker², C. G. Bassa³, A. Dieball⁴, S. Greiss⁵, T. J. Maccarone⁴, G. Nelemans⁶, D. Steeghs⁵, M. A. P. Torres², C. T. Britt¹, J. L. Clem¹, L. Gossen¹, J. E. Grindlay⁷, P. J. Groot⁶, L. Kuiper², E. Kuulkers⁸, M. Mendez⁹, V. J. Mikles¹, E. M. Ratti², N. Rea¹⁰, L. van Haaften⁶, R. Wijnands¹¹, J. J. M. in't Zand²

¹Louisiana State Univ., ²SRON-Netherlands Institute for Space Research, Netherlands, ³University of Manchester, United Kingdom, ⁴University of Southampton, United Kingdom, ⁵University of Warwick, United Kingdom, ⁶Radboud University, Netherlands, ⁷Harvard-Smithsonian, CfA, ⁸ESA/ESAC, Spain, ⁹Groningen University, Netherlands, ¹⁰ICE, CSIC-IEEC, Spain, ¹¹University of Amsterdam, Netherlands. Exhibit Hall

The Chandra Galactic Bulge Survey (CGBS) is a shallow but wide survey of two approximately 6x1 degree strips of the Galactic Bulge about a degree above and below the plane. The survey by design targets regions where extinction and crowding are manageable and optical counterparts are accessible to detailed follow-up. Our strategy is based on going deep enough to detect quiescent low-mass X-ray binaries (LMXBs), but no deeper in order to avoid an excess of cataclysmic variables (CVs), while covering a large area to maximize the numbers of recovered objects. The primary goals of the CGBS are to test predictions of binary evolutionary models through number counts and period distributions of detected sources, and to greatly expand the sample of LMXBs suitable for detailed optical follow-up including mass determination. We have recovered over a thousand X-ray sources most with optical counterparts, and expect these to be divided evenly between quiescent LMXBs, magnetic CVs, and R CVn stars, with smaller numbers of other source types. We are actively pursuing multiwavelength follow-up including searches for optical, infrared, and ultraviolet counterparts, measurement of variability, and optical spectroscopy. So far we have identified about ten candidate LMXBs and CVs and a few other unusual objects such as X-ray selected sdO and carbon stars, both likely products of binary evolution.

This work is supported by the National Science Foundation under Grant No. AST-0908789.

144.25 Chandra And Hst Studies Of The Prototype Ns X-ray Transient, Cen X-4 Samuel Park¹, M. R. Garcia¹

¹Harvard - Smithsonian.

Exhibit Hall

For nearly a century Black holes have been a hot topic, a physical singularity or simply a flawed, all be it brilliant, mathematical concept? Fundamental proof of the existence of black holes lies in the proof of the existence of their event horizons. One such proof lies in the comparison of the X-ray luminosities of black hole and neutron star X-ray transients however this proof assumes that both NS and BH transients continue to accrete at low Mdot during quiescence. Cen X-4 is the prototype NS X-ray transient, and this work is compared to A06020-00, the prototype BH X-ray Transient. As part of this comparison we obtained the first short-wavelength UV spectrum of Cen X-4 in 2004 with HST STIS and obtained simultaneous X-ray data with Chandra. Interestingly, the X-ray flux was found to decrease by a factor of three, while the UV was down by a factor of two. We report on our search for evidence for a disk in the UV and optical spectra, even at these very low Mdot levels. We have extracted the highest quality spectrum from the HST STIS and Chandra data, and compared Cen X -4 to A0620, searching for hints as to the accretion, emission mechanisms and ultimately the existence of their event horizons. This research as been jointly funded by the University of Southampton and the Harvard-Smithsonian center for astrophysics.

144.26

A Chandra Search for Low-mass Companions of Late B Stars in Tr 16

Nancy Remage Evans¹, K. DeGioia-Eastwood², M. Gagne³, L. Townsley⁴, S. Wolk¹, Y. Naze⁵, P. Broos⁴, M. Corcoran⁶, L. Oskinova⁷, A. F. J. Moffat⁸, J. Wang¹, N. Walborn⁹

¹SAO, ²Northern Arizona University, ³West Chester University, ⁴Pennsylvania State University, ⁵Universite de Liege, Belgium, ⁶NASA's Goddard Space Flight Center, ⁷University of Potsdam, Germany, ⁸Universite de Montreal, Canada, ⁹Space Telescope Science Institute. Exhibit Hall

The cluster Tr 16 is included within the area of the large survey of the Carina region with Chandra (PI: Townsley). Stars later than B3 are not known to produce X-rays. On the other hand, low mass stars (later than mid-F spectral type) produce copious X-rays when they are young. We have developed a list of B3 to A0 stars in the young cluster Tr 16 which: 1.) are within 3' of Eta Car, 2.) have an appropriate V and B-V combination (including a range of +/- 0.1 in E(B-V), and 3.) have proper motions consistent with cluster membership. We have identified stars from this list which are X-ray sources on a 90 ksec Chandra image of Tr 16. Presumably the X-rays are produced by a low mass companion, at least in nearly all cases. This attribution is reinforced by the fact that the X-ray sources have higher median temperatures than O and early B sources. In addition, the spectral fits to 4 strongest sources produce temperatures typical of low-mass coronal sources. On this basis, 39% of the late B stars have low mass companions. Interpretation of this number depends on the completeness of the X-ray detections, however discussion of the low mass stars in Tr 16 indicates that stars which will be M stars on the main sequence are detected. N. Evans acknowledges support from the Chandra X-ray Center NASA Contract NAS8-03060

LSI +61 303 And LS5039: More Mysteries Uncovered By Fermi

Richard Dubois¹, Fermi LAT Collaboration

¹SLAC National Accelerator Laboratory.

Exhibit Hall

Results from the first two year of Fermi LAT (Large Area Telescope) observations of the bright sources LS I +61 303 and LS 5039, well observed binary systems at X-ray and TeV energies, have yielded new questions at GeV energies about their nature. These sources are proving to be surprising in terms of spectral behaviour and variability. The exponential cutoff seen in both sources is very reminiscent of the many pulsars Fermi has found, yet the orbital variability is not expected in that interpretation. In addition, LS I +61 303 has shown remarkable, abrupt changes in its flux levels and orbital modulation. In survey mode the LAT observes every point in the sky every 3 hours making it an ideal monitor for these systems.

144.28

Gamma-Ray Emission from Variable Galactic Radio Sources

Chris R. Shrader¹, D. J. Macomb²

¹NASA's GSFC, ²Boise State University.

Exhibit Hall

We describe our ongoing program using data obtained with the Swift/BAT and the Fermi Large Area Telescope to search for hard-X-ray and gamma-ray emission from recently published surveys of galactic radio sources. Radio emission was established as a ubiquitous property of gamma ray sources prior to the launch of Fermi and subsequent examination of the composition of the 1451 source catalog of that mission further supports this idea. Known classes of galactic variable radio sources include high-mass X-ray binaries such as Cyg X-3 and LSI +61 303 which are already established gamma-ray emitters. Those objects are often transient in nature and they are often revealed through survey observations in the hard-X-ray band. Additional objects among this class may be revealed and establishing them as gamma-ray emitters would be of great interest. Other possible source classes include magnetars, RRATs (Rotating Radio Transients) and flare stars. Most interestingly, totally unexpected phenomena could also be revealed. We will describe our sample selection, data extraction and analysis methods and present results obtained to date.

144.29

Gamma-ray/x-ray Observations Of The Be-pulsar Binary 1a0535+262 During A Major Outburst Angelo Varlotta¹, G. Maier², VERITAS

¹Purdue University, ²Deutsches Elektronensynchrotron (DESY), Germany. Exhibit Hall

The detection of Cyg X-1, PSR B1259-63, LS 5039 and LS I +61 303 at TeV energies have established X-ray binaries as a new class of VHE gamma-ray emitters. In this work, we report results from gamma-ray and X-ray observations of 1A035+262 during a major outburst in December 2009. The TeV gamma-ray data were obtained with VERITAS (0.1-30 TeV). We also used public Fermi/LAT data to cover the GeV band (0.1-300 GeV). The X-ray data were obtained with the RXTE/PCA (2-60 keV) and Swift/XRT (0.3-10 keV). The observations provided a good coverage of the X-ray outburst, as well as the binary orbit. 1A0535+262 was not detected at TeV or GeV energies. This is consistent with the fact that the observed X-ray continuum can be described as the combination of blackbody and Comptonized emission from thermal electrons (presumably in the accretion disk and "corona") and that the source radiates little at radio wavelengths. The lack of non-thermal electrons distinguishes the source from those Be X-ray

binaries (such as PSR B1259-63 and LS I +61 303) that have been detected at GeV-TeV energies. We discuss the implications of the results on theoretical models.

145

Career Paths, Professional Development, and STEM Diversity Poster Session *Exhibit Hall*

145.01

The Astronomer's H-R diagram

Alberto Conti¹, S. Lowe², A. Accomazzi³, G. DiMilia³ ¹STScl, ²LCOGT, ³ADS.

Exhibit Hall

Most people who've taken an astronomy course are familiar with the Hertzsprung-Russell diagram. It was developed to show the relationships between the temperature (or colour) of a star and its luminosity. Following this premise and an original idea by Stuart Lowe, we asked ourselves if american astronomer as a group have a "Main Career Sequence" in the space of Peer Reviewed papers and "absolute" Google index. Here we expand on Stuart's original idea examining several cuts in publication and Google parameter space with the help of proper ADS data

145.02

Career Outcomes for Astronomy Ph.D. Graduates of the University of Texas at Austin: The Next Generation

Harriet L. Dinerstein¹

¹Univ. of Texas, Austin.

Exhibit Hall

Sixteen years ago I conducted a survey of the career trajectories and outcomes of 78 individuals who earned Ph.D.s from the Department of Astronomy at the University of Texas at Austin during the period 1984-1995 (Dinerstein, H. 1996, AAS, 189.0501). In the current poster I extend these statistics up to the present, adding 68 Ph.D. recipients from 1996-2010. This is a sufficiently large sample to search for secular trends such as possible changes in duration of the postdoctoral stage, redistribution of demographics among different kinds of long-term positions, and the emergence of new categories of astronomy-related employment. The picture is less discouraging than one might expect. As of 2010, about 75% of the Texas graduates 7 - 14 years past the Ph.D. are still doing astronomy, and most of those in non-astronomical careers left the field by choice (and often have had considerable success in their alternate careers). Of those 6 years or less past the Ph.D., 50% were in postdoctoral positions and less than 10% had left astronomy. Recent reconsiderations of the employment market (Metcalfe, T.S. 2008, PASP, 120, 229; Seth, A. 2009, Astro2010: The Astronomy and Astrophysics Decadal Survey, Position Paper No. 51) make the point that a typical astronomer who ultimately achieves a permanent position will have held two or three prior temporary positions; this was equally true three decades ago. There has been notable growth nationwide in the number of astronomers employed as faculty at small liberal arts colleges and other undergraduate-centered institutions, a trend that to some degree was anticipated by the University of Texas cohort, which included a number of students for whom this was their personal goal. In a world where job certainty is no longer so prevalent, motivated and resourceful astronomers are finding ways to remain active members of our community.

AstroBetter: A Blog and Wiki for Professional Astronomers

Kelle L. Cruz¹, J. Lu², J. Rigby³, E. Bressert⁴, T. Robitaille⁵, M. Huerta⁶, S. Dhital⁷ ¹Hunter College/CUNY & AMNH, ²Caltech, ³Greenbelt, MD, ⁴University of Exeter, United Kingdom,

⁵Harvard/CfA, ⁶Gentleman Scholar, ⁷Vanderbilt.

Exhibit Hall

AstroBetter.com is a multi-contributor blog and wiki website designed for information sharing among professional astronomers. The goal of the site is to increase the productivity of astronomers by creating a centralized location for tips and tools of our multifaceted trade. Our content includes topics related to data reduction and analysis, general computing, writing papers and proposals, giving talks, teaching, career planning, productivity, organization, and diversity and equity in science and education. While we have several contributors, the site is intended to be community driven and we encourage everyone to publish to the wiki, submit guest posts, suggest post ideas, and to comment on blog entries. One of our primary goals is to consolidate and reduce the transient nature of the astronomy community's collective knowledge base by having an active wiki. Currently, the most common way to share astro-centric tools and tips that are not appropriate for a published paper, is to put them on an individual's website. However, the average astronomer's website will have at least four different addresses over the course of their career and only the site owner can edit the content. As a result, information on personal websites goes stale very quickly and dead links to such sites abound. It is our hope that community maintained wikis, such as the one hosted on AstroBetter, will gradually replace the personal website. In this poster we introduce the contributors to AstroBetter, show statistics about our current readership, give excerpts of some of our most popular posts and wiki entries, and show how anyone can add or edit content on the wiki. The goal of this poster is to spread the word about AstroBetter and increase our community of readers and wiki editors, because together, we can AstroBetter.

145.04

LGBT Workplace Issues for Astronomers

Laura E. Kay¹, R. Danner², K. Sellgren³, V. Dixon⁴, GLBTQastro

¹Barnard College, ²Northrup Grumman Aerospace Systems, ³Ohio State University, ⁴Johns Hopkins Univ.. Exhibit Hall

Federal Equal Employment Opportunity laws and regulations do not provide protection from discrimination on the basis of sexual orientation or gender identity or gender expression. Sexual minority astronomers (including lesbian, gay, bisexual and transgender people; LGBT) can face additional challenges at school and work. Studies show that LGBT students on many campuses report experiences of harassment. Cities, counties, and states may or may not have statutes to protect against such discrimination. There is wide variation in how states and insurance plans handle legal and medical issues for transgender people. Federal law does not acknowledge same-sex partners, including those legally married in the U.S. or in other countries. Immigration rules in the U.S. (and many other, but not all) countries do not recognize same-sex partners for visas, employment, etc. State `defense of marriage act' laws have been used to remove existing domestic partner benefits at some institutions, or benefits can disappear with a change in governor. LGBT astronomers who change schools, institutions, or countries during their career may experience significant differences in their legal, medical, and marital status.
Commitment to Broadening Participation at NOAO

Catharine D. Garmany¹, D. Norman¹

¹National Optical Astronomy Observatory.

Exhibit Hall

AURA and NOAO take seriously the importance of Broadening Participation in Astronomy. At the request of the AURA President, each of the AURA centers (NOAO, NSO, STSCI, Gemini) appointed a Diversity Advocates (DA). At NOAO this job is shared by Dara Norman and Katy Garmany, who were appointed by Dave Silva in Jan 2009. The DA's are members of the AURA Committee on Workforce and Diversity (WDC), a designated subcommittee of the AURA Board of Directors. The role of this committee includes reviewing activities and plans on an AURA wide basis aimed at broadening the participation within AURA, and reviewing AURA wide policies on the workforce. At NOAO, the role of the DAs spans a number of departments and activities. They serve on observatory search committees, and offer suggestions on how NOAO job searches can reach the most diverse audience. The DA's job is to insure that NOAO actively pursues every opportunity to increase diversity: to this end they are involved in outreach and educational activities that focus on workplace development and encourage inclusion of woman, minorities and persons with disabilities.

145.06

Current Results and Future Directions of the Pulsar Search Collaboratory

Sue Ann Heatherly¹, R. Rosen¹, M. McLaughlin², D. Lorimer²

¹NRAO, ²West Virginia University.

Exhibit Hall

The Pulsar Search Collaboratory (PSC) is a joint partnership between the National Radio Astronomy Observatory (NRAO) and West Virginia University (WVU. The ultimate goal of the PSC is to interest students in science, technology, engineering, mathematics (STEM) fields by engaging them in conducting authentic scientific research—specifically the search for new pulsars.

Of the 33 schools in the original PSC program, 13 come from rural school districts; one third of these are from schools where over 50% participate in the Free/Reduced School Lunch program. We are reaching first generation college-goers. For students, the program succeeds in building confidence in students, rapport with the scientists involved in the project, and greater comfort with team-work. We see additional gains in girls, as they see themselves more as scientists after participating in the PSC program, which is an important predictor of success in STEM fields. The PSC has had several scientific successes as well. To date, PSC students have made two astronomical discoveries: a 4.8-s pulsar and bright radio burst of astrophysical origin, most likely from a sporadic neutron star.

We will report on the status of the project including new evaluation data. We will also describe PSC-West, an experiment to involve schools in Illinois and Wisconsin using primarily online tools for professional development of teachers and coaching of students. Knowledge gained through our efforts with PSC-West will assist the PSC team in scaling up the project.

The California-Arizona Minority Partnership for Astronomy Research and Education (CAMPARE): an Educational Experience for Undergraduates at the University of Arizona Alumni Association's Astronomy Camp.

Courtney Lemon¹, D. McCarthy², A. Rudolph¹

¹California State Polytechnic University, Pomona, ²University of Arizona. Exhibit Hall

The California-Arizona Minority Partnership for Astronomy Research and Education (CAMPARE) is an NSF-funded partnership between the Astronomy Program at Cal Poly Pomona (CPP) and the University of Arizona Steward Observatory designed to promote participation of underrepresented minorities (including women) in astronomy research and education. As part of the education component of the program, CPP undergraduate physics majors and minors are eligible to work as a counselor at the University of Arizona's Astronomy Camp, one of the premier astronomy outreach opportunities in the world. CAMPARE students have the opportunity to work in this learn-by-doing environment with a wide range of students to gain first hand experience of teaching astronomy to students of a wide variety of ages in highly structured educational setting. Cal Poly Pomona students who are interested in education, both formal and informal, work in a variety of camps, from Girl Scout camps to camps for advanced high school students, to further their understanding of what it means to be a professional in the field of education. The CAMPARE student who participated in this program during summer 2010 had the opportunity to work under Dr. Don McCarthy, camp director of University of Arizona's Astronomy Camps for 20 years, and observe the interpersonal relations between campers and staff that is so vital to the learning the students receive. Through these observations, the CAMPARE student was able to learn to gauge students' interest in the material, and experience real life teaching and learning scenarios in the informal education realm.

145.09

The Lowell Observatory Predoctoral Scholar Program

Lisa A. Prato¹

¹Lowell Observatory.

Exhibit Hall

Lowell Observatory is pleased to solicit applications for our Predoctoral Scholar Fellowship Program. Now beginning its fourth year, this program is designed to provide unique

research opportunities to graduate students in good standing, currently enrolled at Ph.D. granting institutions. Lowell staff research spans a wide range of topics, from astronomical instrumentation, to icy bodies in our solar system, to exoplanet science, to stellar populations and dwarf irregular galaxies. First light with the observatory's

new 4.2 meter Discovery Channel Telescope is expected in 2011, making this a particularly exciting time in our history. Student research is expected to lead to a thesis dissertation appropriate for graduation at the doctoral level at the student's home institution. Currently, five students are enrolled in our program; our first graduate completed the program in August, 2009. The Observatory provides competitive compensation and full benefits to student scholars. For more information, see

http://www.lowell.edu/rsch/predoc.php and links therein.

Applications for Fall 2011 are due by May 1, 2011.

POCA Update: An NSF PAARE Project

Donald K. Walter¹, S. D. Brittain², J. L. Cash¹, D. H. Hartmann², S. B. Howell³, J. R. King², M. D. Leising², E. A. Mayo¹, K. J. Mighell³, D. M. Smith, Jr.¹

¹South Carolina State Univ., ²Clemson University, ³National Optical Astronomy Observatory. Exhibit Hall

We report on the status of "A Partnership in Observational and Computational Astronomy (POCA)" under the NSF's "Partnerships in Astronomy and Astrophysics Research and Education (PAARE)" program. This partnership includes South Carolina State University (a Historically Black College/University), Clemson University (a Ph.D. granting institution) and the National Optical Astronomy Observatory. We have reached the midpoint of this 5-year award and discuss the successes, challenges and obstacles encountered to date. Included is a summary of our summer REU program, the POCA graduate fellowship program, faculty research capacity building, outreach activities, increased use of NSF facilities and shared resources. Additional POCA research presentations by the authors are described elsewhere in these proceedings. Support for this work was provided by the NSF PAARE program to South Carolina State University under award AST-0750814 as well as resources and support provided by Clemson University and the National Optical Astronomy Observatory.

146

HAD III History Poster Papers Poster Session Exhibit Hall

146.01

Al-Sufi's Investigation of Stars, Star Clusters and Nebulae

Ihsan Hafez¹, F. R. Stephenson¹, W. Orchiston¹

¹James Cook University, Australia.

Exhibit Hall

The distinguished Arabic astronomer, Al-Sufi (AD 903-986) is justly famous for his Book of the Fixed Stars, an outstanding Medieval treatise on astronomy that was assembled in 964. Developed from Ptolemy's Algamest, but based upon al-Sufi's own stellar observations, the Book of the Fixed Stars has been copied down through the ages, and currently 35 copies are known to exist in various archival repositories around the world. Among other things, this major work contains 55 astronomical tables, plus star charts for 48 constellations. For the first time a long-overdue English translation of this important early work is in active preparation.

In this paper we provide biographical material about Al-Sufi and the contents of his *Book of the Fixed Stars*, before examining his novel stellar magnitude system, and his listing of star clusters and nebulae (including the first-ever mention of the Great Nebula in Andromeda).

146.02

Kepler's "War on Mars"

William Dorsey¹, W. Orchiston¹, F. R. Stephenson¹

¹James Cook University, Australia.

Exhibit Hall

This paper presents an interpretation of how Johannes Kepler changed the study of astronomy. We propose that in his metaphorical "War on Mars," the *Astronomia Nova*, Kepler used a revolutionary rhetoric to bring about the usurpation of seventeenth-century astronomy. We discuss how Kepler approached the well-established conceptual framework within which the hypotheses of Ptolemy, Copernicus and Tycho Brahe functioned, and how he sought comprehensive physical principles that

could determine the true cause and form of the known Universe. We examine Kepler's need to redefine reality and his use of rhetoric in shaping his astronomical argument for a new astronomy, and we show that his new 'laws' represent a fusion of physics and geometry based upon astronomical observations. We suggest that although Kepler may have believed in and defended some Copernican ideas, his innovative *Astronomia Nova* opened up a whole new vista for international astronomy.

146.03

The First Three Catalogues of Southern Star Clusters and Nebulae

Glen Cozens¹, W. Orchiston¹, A. Walsh¹

¹James Cook University, Australia.

Exhibit Hall

Nicolas de la Caille, James Dunlop and John Herschel compiled the first three catalogues of southern star clusters and nebulae. Lacaille catalogued 42 objects from Cape Town, South Africa, in 1751 and 1752. Dunlop catalogued 629 objects from Parramatta, Australia, in 1826 and Herschel catalogued 1708 objects between 1834 and 1838 from Cape Town. Many of these objects had not been seen before; In this paper we discuss the new discoveries and the accuracy of the positions supplied by Lacaille, Dunlop and Herschel. Half of Dunlop's 629 objects turned out to be asterisms and faint double stars.

146.04

Early Scientific Astronomy on the American Northwest Coast: Captain Cook's Sojourn at Nootka Sound in 1778

William Wells¹, W. Orchiston²

¹*Retired Engineer,* ²*James Cook University, Australia.*

Exhibit Hall

Between 1768 and 1778 England's premier maritime explorer, James Cook, made three much-published and very successful expeditions to the Pacific, when important contributions were made to anthropology, botany and zoology, not to mention maritime astronomy. Astronomy played a vital role in navigation and coastal cartography, and consequently there were astronomers on all three Pacific expeditions. On the final voyage Cook would lose his life in Hawaii, but not before exploring the northwest coast of the American continent. Three astronomers, Bayly, King and Cook himself, formed part of retinue of this two-vessel expedition, and during the sojourn of the *Resolution* and *Discovery* at Nootka Sound they set up their observatories and used a variety of instruments to carry out important astronomical observations.

In this paper we review the rationale for Cook's third voyage, discuss the Nootka Sound stop-over, provide biographical information about Bayly, Cook and King, examine their scientific instruments and review their astronomical observations.

146.05

Williamstown Observatory and the Development of Professional Astronomy in Australia Jenny Andropoulos¹, W. Orchiston¹, B. Clark¹

¹James Cook University, Australia.

Exhibit Hall

During the early 1850s the colony of Victoria was enjoying a succession of gold rushes, and as the population of the fledgling settlement of Melbourne rapidly grew, an urgent need arose for an accurate local time service. Thus, Williamstown Observatory was founded at the port of Williamstown in 1853. Under the dynamic direction of Robert Ellery, the Williamstown Observatory quickly added meteorological and tidal observations, geodetic surveying and non-meridian astronomical observations to its portfolio, and by the time it closed in 1863 it had already played a key role in the early development of professional astronomy in Australia. Ellery went on to direct Melbourne

Observatory-Williamstown's successor-and in the process build an international reputation in astronomy, meteorology and scientific entrepeneurship.

In this paper we will discuss the founding and chequered history of the Williamstown Observatory, its scientific instruments and the ways in which they were used to contribute to Australian and international astronomy.

146.06

The USNO 26" Clark Refractor; From Visual Observations to Speckle Interferometry

Jennifer L. Bartlett¹, B. D. Mason¹, W. I. Hartkopf¹

¹US Naval Observatory.

Exhibit Hall

Before addressing queries about how and what to preserve among astronomical devices, the question of what constitutes a historic instrument must be considered. Certainly, the lenses are the defining feature of a Clark refractor. Since 1867, when Newcomb inquired about the possibility of obtaining a great glass from Alvan Clark & Sons, the U.S. Naval Observatory 26-in (66-cm) equatorial has evolved in response to improvements in technology and changes in its observing program. After two major overhauls, only the objective remains of the equipment originally installed by the Clarks in 1873 at the old Observatory site in Foggy Bottom. However, the telescope retains its reputation as a historic Clark refractor.

The USNO telescope was briefly renowned as the largest refractor in the world; the second of five such achievements by the Clarks. Through it, Hall first detected the moons of Mars in 1877. However, by that time, the Clarks had already refigured the flint glass. Hall and Gardiner had also altered the drive mechanism.

When the USNO moved to its present Georgetown Heights location in 1893, the great equatorial was refurbished with its original Clark optics installed on a more robust Warner & Swasey mount. Peters eventually incorporated discarded parts from the original mounting into his photographic telescopes during the first half of the 20th century. The 26'' refractor underwent further modernization in the early 1960s to facilitate the xy-slide of a Hertzsprung-style photographic double star camera. In 1965, the objective was disassembled for cleaning and reassembled with new spacers. The most recent maintenance included re-wiring and replacing several motors and the hand paddles. Originally designed as a visual instrument, the USNO 26'' Clark refractor now hosts a speckle interferometer for its current double star program. Despite continuing modifications, this telescope remains a fine example of the optician's art.

146.07

The 1882 Transit of Venus and the Popularisation of Astronomy through the Pages of the *New York Times*

Stella Cottam¹, W. Orchiston¹, F. R. Stephenson¹

¹James Cook University, Australia.

Exhibit Hall

After the disappointments of the 1761 and 1769 transits of Venus, the nineteenth century pair, in 1874 and 1882, offered astronomers the next opportunity to use these rare events in a bid to pin down a value for the solar parallax and hence that fundamental yardstick of Solar System astronomy, the astronomical unit. Only the 1882 transit was visible from the USA, and on the fateful day amateur and professional observers were scattered across the nation. While the value for the solar parallax derived from their combined observations was a significant improvement on the range of values obtained in the eighteenth century, there was considerable disquiet about the logic of using transits of Venus in this way when alternative approaches were available.

In this paper we discuss some of the observers who observed the 1882 transit from American soil, summarise the scientific results from the overall American endeavour and examine ways in which reports on the transit in the pages of the *New York Times* helped generate a heightened public awareness of astronomy.

146.08

The IAU Early French Radio Astronomy Project

Wayne Orchiston¹, A. Boischot², J. Delannoy², M. Kundu³, J. Lequeux², M. Pick², J. Steinberg² ¹James Cook University, Australia, ²Paris Observatory, France, ³University of Maryland. Exhibit Hall

In 2006 an ambitious project was launched under the auspices of the IAU Working Group on Historic Radio Astronomy to document important developments in French radio astronomy from 1901 through to the 1960s, in a series of papers published, in English, in the *Journal of Astronomical History and Heritage*. This successful project has now come to an end with the sixth and final paper in the series about to be published (and a new WG project, on the history of early Japanese radio astronomy, has just been launched).

In this paper we discuss Nordmann's abortive attempt to detect solar radio emission in 1901, and the important roles played by staff from the École Normale Supérieure and the Institut d'Astrophysique in Paris during the 1940s through 60s in developing new radio astronomy instrumentation and pursuing a range of solar and non-solar research projects in Paris itself and at field stations established at Marcoussis, Nançay and the Haute Provence Observatory.

146.09

Van Vleck Observatory and the Role of the Large Refractor in Parallax Studies

Ian Glass¹, J. Griese, III¹, W. Orchiston¹

¹James Cook University, Australia.

Exhibit Hall

The second half of the nineteenth century was the era par excellence of the 'large refractor' as the aperture of the world's largest refractor quickly rose to 40 inches, thanks in no small part to the critical role played by the firm of Alvan Clark & Sons. One of the research projects these long focal length telescopes were especially suited to was the determination of stellar parallaxes, and this research focus continued into the twentieth century. In 1922 a 20-inch f/16.5 Clark refractor was installed at the Van Vleck Observatory at Wesleyan University in Middletown, Connecticut, and this telescope was used to determine stellar parallaxes that were subsequently published by van Altena, Lee, and Hoffleit in *The General Catalogue of Trigonometric Stellar Parallaxes*, Fourth Edition (1995). After providing background information on refractor construction and parallax studies during the nineteenth century this paper focuses on the Van Vleck Observatory parallax program, which continued through into the 1990s, by which time HIPPARCHOS had been launched.

146.10

The Contribution of an Experimental WWII Radar Antenna to Australian Radio Astronomy Wayne Orchiston¹, H. Wendt¹

¹James Cook University, Australia.

Exhibit Hall

During the late 1940s and throughout the1950s Australia was one of the world's foremost astronomical nations owing primarily to the dynamic Radio Astronomy Group within the Commonwealth Scientific and Industrial Organisation's Division of Radiophysics. The earliest celestial observations were made with former WWII radar antennas and simple Yagi aerials, before more sophisticated purpose-built radio telescopes of various types were designed and developed.

One of the recycled WWII antennas that was used extensively for pioneering radio astronomical research was an experimental radar antenna that initially was located at the Division's short-lived Georges Heights field station but in 1948 was relocated to the new Potts Hill field station in suburban Sydney. In this paper we describe this unique antenna, and discuss the wide-ranging solar, Galactic and extragalactic research programs that it was used for.

146.11

History of Astronomy at James Cook University, Australia

Wayne Orchiston¹, H. Duerbeck¹, I. Glass¹, K. Malville¹, B. Marsden¹, I. Simonia¹, B. Slee¹, F. R. Stephenson¹, R. Strom¹, I. Whittingham¹, R. Wielebinski¹

¹James Cook University, Australia.

Exhibit Hall

The Centre for Astronomy at James Cook University (JCU) in Australia has been offering totally internetdelivered Master of Astronomy degrees since 2003 and Doctor of Astronomy and Ph.D. degrees since 2004. In 2005 a new dimension was added with unique offerings in the history of astronomy at both Masters and Doctoral levels. With the aid of 1 full-time staff member and 10 adjunct staff, 4 students have now graduated with Ph.D. degrees, 1 student died from cancer after completing the first draft of his thesis, and 14 students are currently enrolled in Ph.D. degrees. In addition 12 students have completed Master of Astronomy degrees in history of astronomy, and there are 3 students who are currently enrolled for Masters degrees. As part of its commitment to the international development of history of astronomy, the Centre for Astronomy also arranges boutique 'invitation only' history of astronomy conferences in March each year, and produces the *Journal of Astronomical History and Heritage*.

146.12

Filling a Void: The Life and Times of the Journal of Astronomical History and Heritage Wayne Orchiston¹, H. Duerbeck¹, J. S. Tenn²

¹James Cook University, Australia, ²Sonoma State University.

Exhibit Hall

In 1998 the *Journal of Astronomical History and Heritage* (JAH²) was launched as a new outlet for those wishing to publish papers on the history of astronomy. The journal has since developed rapidly and become an important publication venue for those conducting research in all fields of historical astronomy, including aspects of Asian and Oriental astronomical history. With support from a distinguished international Editorial Board, the journal has grown from two issues per year to three, and now features increasing numbers of colour pages. In this paper we review the founding and development history of the journal, examine the range of research and review papers that have been published since 1998, and discuss some of the possible future directions that we are currently exploring.

147 *Dwarf Galaxies* Poster Session *Exhibit Hall*

147.01

Simulating Cosmic Rays in the Large Magellanic Cloud

Paul M. Ricker¹, Y. Chu¹, B. D. Fields¹, R. Gruendl¹

¹Univ. of Illinois.

Exhibit Hall

Fermi observations of the Large Magellanic Cloud (LMC) strongly support the idea that cosmic-ray acceleration is associated with regions of ongoing massive star formation. Because it is so close, the LMC is well-resolved in a variety of wavebands, and existing observations place good constraints on its gas distribution and recent star formation history. These facts make the LMC an excellent validation case for the numerical models of cosmic rays used in galaxy cluster simulations. We present preliminary results from a project to incorporate cosmic-ray acceleration and transport into the FLASH adaptive mesh refinement (AMR) simulation code, with particular emphasis on the use of LMC observations to constrain the acceleration efficiency and diffusive length scales of cosmic rays. This research is supported by NASA under Fermi Guest Investigator grant NNX10AO78G.

147.02

Molecular Hydrogen Images of Star Forming Regions in the Magellanic Clouds

Ronald G. Probst¹, R. Barba², A. Bolatto³, Y. Chu⁴, S. Points⁵, M. Rubio⁶, C. Smith⁵ ¹NOAO, ²Universidad de La Serena, Chile, ³University of Maryland, ⁴University of Illinois, ⁵NOAO, Chile, ⁶Universidad de Chile, Chile.

Exhibit Hall

The Large and Small Magellanic Clouds exhibit a variety of star formation physics with multiple phase components in low metallicity, gas rich environments. The ~10 K, ~100 K, and ~10⁴ K regimes are well explored. We are imaging LMC and SMC star forming regions in 2.12 micron H_2 emission which arises in the ~1000 K transition zone of molecular clouds. This is an NOAO Survey program using the widefield IR camera NEWFIRM on the CTIO 4-m Blanco telescope during its limited southern deployment. The data set will have immediate morphological applications and will provide target selection for followup infrared spectroscopy. We will provide a public archive of fully calibrated images with no proprietary period.

NOAO is operated by the Association of Universities for Research in Astronomy, under cooperative agreement with the National Science Foundation.

147.03

The Large Magellanic Cloud In The Sdss And Lcdm: Is There A "Found Satellites Problem"?

Erik J. Tollerud¹, E. J. Barton¹, J. S. Bullock¹, C. Trinh², M. Boylan-Kolchin¹

¹University of California Irvine, ²University of Sydney, Australia. Exhibit Hall

Substructure in LCDM provides a number of interesting puzzles. While the missing satellites problem is well-studied, there are suggestions of an opposite problem on the bright end. Subhalos large enough to host luminous satellites are uncommon, so we investigate whether the existence of the Large Magellanic Cloud (LMC) orbiting the Galaxy is a challenge for LCDM. We construct a volume limited sample of isolated galaxies in the Sloan Digital Sky Survey (SDSS) within which all LMC analogs would be visible. We search this sample for analogs to an isolated galaxy pair like the Milky Way/LMC system and interpret these results with cosmological simulations. We find that a significant fraction of Milky Way-

like hosts host LMC-like satellites, closely matching the predictions of n-body simulations. However, we find that the LMC is remarkably blue for such satellites. This could imply that the LMC is on first infall as recent proper motions suggest.

147.04

The Chemical Composition Of Ultra-faint Dwarf Galaxies

Anna Frebel¹, J. D. Simon², E. N. Kirby³

¹Harvard-Smithsonian Center for Astrophysics, ²Carnegie Observatory, ³Caltech. Exhibit Hall

We present recent high-resolution spectroscopic observations of extremely metal-poor stars located in the ultra-faint dwarf galaxies Ursa Major II, Coma Berenices, Leo IV, Segue 1 and Bootes II. Their chemical abundance patterns resemble those found in halo stars of comparable metallicty, suggesting that chemical evolution was universal, at least in the very low-metallicity regime, before the onset of SN Ia. This chemical similarity lends support to the idea that systems like the surviving dwarfs played a significant role in the assembly of (at least) the metal-poor outer halo of the Galaxy.

147.05

Observations of Dwarf Galaxies in Several Photometric Systems

Joanne D. Hughes¹, R. Leaman², K. McCormick¹, A. Hankins¹

¹Seattle Univ., ²University of Victoria, Canada.

Exhibit Hall

Using the SPIcam imager at the Apache Point 3.5-m telescope, we have observed the ultra-faint dSph, UMa II (d~30 kpc), and the WLM dIrr galaxy (d~ 930 kpc) in Washington and Strömgren filters. UMa II is a nearby metal-poor system ([Fe/H]~-2.5), within the dark matter halo of the Milky Way, with few red giant branch stars above the horizontal branch. Previous spectroscopic studies have confirmed that UMa II is old (~12 Gyr), contains some stars more metal-poor than [Fe/H]=-3.0, and has a ~1.0 dex metallicity spread. The WLM Galaxy is more metal rich (mean [Fe/H]~ -1.3) than UMa II, with the bright RGB population being dominated by young and relatively more metal-rich stars. There is a metallicity gradient within the WLM dIrr, with the inner-galaxy population being at least 0.3 dex more metal rich ([Fe/H]~ -1.1) than the outer halo ([Fe/H]~ -1.4). We present our new imaging data and compare the stellar population color-magnitude diagrams with theoretical models to determine the best photometric methods of quantifying metallicity spreads in these diverse populations. We show that photometric metallicities can be determined to ~0.2 dex for bright RGB stars and to ~0.15 dex for well-defined giant branches.

We acknowledge support from NSERC Discovery Grants and the M.J. Murdock Charitable Trust.

147.06

Clustering of Milky Way Dwarf Galaxies

Brandon Bozek¹, R. F. G. Wyse¹, G. F. Gilmore²

¹Johns Hopkins University, ²Institute of Astronomy, University of Cambridge, United Kingdom. Exhibit Hall

The distribution of Milky Way Dwarf Galaxies has been suggested to contain anisotropic subsets of 'ghostly streams' and groups or even to be distributed in a flattened 'Disk of Satellites'. Recent surveys have facilitated the discovery of larger numbers of satellites and we investigated their distribution using a suite of clustering estimators. We also applied the same analysis to the Via Lactea II dark matter simulation and several subsamples selected following recent suggestions. We consider both all dwarf galaxies within 260 kpc and a subset of only those found within the northern contiguous portion of the SDSS DR7 Legacy Footprint. We will present our results and discuss their interpretation.

The Dwarf Galaxy Population of the M81 Group

Kristin Chiboucas¹, B. A. Jacobs², I. D. Karachentsev³, R. B. Tully²

¹Gemini Observatory, ²University of Hawaii, ³Special Astrophysical Observatory, Russian Federation. Exhibit Hall

In a CFHT/Megacam imaging survey of the M81 Group to search for the smallest dwarf galaxies, we identified 22 new candidate dwarf galaxies. Follow-up HST ACS and WFPC2 imaging in F814W and F606W bands was used to produce color-magnitude diagrams down to 1.5-3 mag below the tip of the red giant branch. From tip of the red giant branch distances, we establish 14 out of the 22 candidates as bona-fide group members, including 3 blue compact dwarfs, 1 likely tidal dwarf, and a dwarf spheroidal galaxy as faint as $M_R = -6.9$. The latter is within the domain of the ultra-faint dwarf galaxies recently discovered in the Local Group. As the original survey extended out to the group second turnaround radius, and based on detection limits determined from simulations, we believe our sample of M81 group galaxy members is largely complete down to $M_R = -9.5$. We discuss the properties of the M81 Group dwarf galaxy population.

147.08

Nearby Dwarf Galaxies in VLA-ANGST: an Exploration of HI Velocity Dispersion

Adrienne Stilp¹, J. Dalcanton¹, J. Ott², S. Warren³, D. Weisz¹

¹University of Washington, ²National Radio Astronomy Observatory, ³University of Minnesota. Exhibit Hall

The interplay between star formation and the interstellar medium (ISM) is critical for shaping the baryonic component of galaxies. We probe the present-day structure of the ISM through neutral hydrogen (HI) observations of nearby dwarf galaxies from the Very Large Array ACS Nearby Galaxy Survey Treasury (VLA-ANGST) Project, complemented by extensive HST imaging from ANGST that allows us to accurately constrain the recent star formation histories of these galaxies on spatial scales of ~100 pc. We find a clear lower limit to the HI velocity dispersion in every sample galaxy. We explore the possible causes of this limit by examining its properties at varying surface densities as well as any potential correlation with star formation in the last 500 Myr.

147.09

Connecting HI Kinematics and Physical Processes in Dwarf Galaxies' ISM

Sean Markert¹, A. Stilp¹, J. Dalcanton¹, T. Quinn¹, F. Governato¹

¹University of Washington.

Exhibit Hall

We present a comparison of the HI velocity dispersion in cosmological simulations of dwarf galaxies to the VLA-ANGST sample of observed dwarfs. The observations show a clear lower limit to the velocity dispersion in these galaxies. Using state-of-the-art simulations we explore the physical processes that could cause this limit, such as feedback from star formation and effects of gas temperature. We then use the simulations to show the impact these processes have on the interstellar medium in our sample of observed dwarfs.

The Cold ISM of Low Metallicity Galaxies

Steven R. Warren¹, E. Skillman¹, A. Stilp², J. Ott³, J. Dalcanton², F. Walter⁴

¹University of Minnesota, ²University of Washington, ³NRAO, ⁴Max Planck Institut für Astronomie, Germany.

Exhibit Hall

Star formation occurs primarily within molecular clouds, and the raw material for molecular cloud formation is the reservoir of neutral hydrogen (HI) gas present in star forming galaxies. Thus, understanding how and where the HI is converted into molecular gas is a key step in our understanding of the star formation process. At low metallicities, the key tracer of molecular gas, CO, is not detected. Identifying narrow line HI emission (e.g., Young et al. 1996, 1997) provides a potential tracer of the molecular phase by tracing the cold HI gas. The cold HI is believed to be a necessary phase in converting the ubiquitous warm HI gas into cold molecular gas. In the current study, we have characterized the locations of

narrow HI emission through ine-of-sight spectra of HI line maps taken from the Very Large Array - ACS Nearby Galaxy Survey Treasury (VLA-ANGST) and The HI Nearby Galaxy Survey (THINGS) projects. We detect narrow HI emission in every galaxy surveyed where the signal to noise in a given spectrum is high enough (~15-20) to provide statistically viable fits. The detected narrow HI emission constitutes ~1-20% of the total surveyed HI in a given galaxy. The locations of the cold HI gas can be compared with tracers of recent star formation to better understand the star formation process.

147.11

Star Formation and Integrated Optical Colors from the Local Volume Legacy Survey

Cody Minns¹, B. R. Shackleford¹, L. van Zee¹, S. Friberg², K. L. Barnes¹, S. Sakai³, LVL Team ¹Indiana University, ²University of Massachusetts, ³University of California. Exhibit Hall

We present results of an optical imaging study of 73 galaxies from the Spitzer Local Volume Legacy (LVL) survey. The broadband and narrowband optical images were analyzed in order to determine information about global star formation rates, histories, and evolution of these nearby galaxies. The observed UBVR colors are consistent with the expected colors of star forming galaxies, with B-R colors ranging from 0.4 to 1.4. The blue, low mass galaxies appear to have a wider dispersion of current-to-past star formation rates than the more massive spiral galaxies in the sample. These results are discussed in the context of possible star formation histories for galaxies in the Local Volume.

147.12

Optical Color and Equivalent Width Gradients in the Local Volume Legacy Survey

Bryce Shackleford¹, C. R. Minns¹, L. van Zee¹, S. Friberg², K. L. Barnes¹, S. Sakai³, LVL Team ¹Indiana University, ²University of Massachusetts, ³University of California. Exhibit Hall

We present the results of B, R, and H alpha optical imaging of a subsample of galaxies from the Spitzer Local Volume Legacy Survey. The images were analyzed using a set of concentric, co-eccentric ellipses to measure surface brightness profiles and color gradients. While most of the galaxies in this sample have modest to negligible color gradients, some of the galaxies have B-R color gradients greater than 0.4 mag/kpc. Furthermore, the range of values measured for the B-R color gradient is larger for galaxies with absolute magnitudes fainter than -16. Likewise, the scatter in the observed equivalent width gradient is larger for the low mass irregular galaxies. The increased range of observed color gradients in the low mass galaxies may be related to a transition in the dominant mechanisms that regulate star formation in dwarf irregular and spiral galaxies.

Stellar Mass Distributions in Dwarf Irregular Galaxies

Hongxin Zhang¹, D. Hunter¹, LITTLE THINGS Team

¹Lowell Observatory.

Exhibit Hall

We present the radial distributions of the stellar mass and the star formation histories for a large sample of dwarf irregular galaxies assembled by the LITTLE THINGS project (Local Irregulars That Trace Luminosity Extremes The HI Nearby Galaxy Survey,

http://www.lowell.edu/users/dah/littlethings/index.html). Specifically, utilizing the multi-band data including FUV/NUV/UBV/H α /3.6 μ m, and with the CB07 stellar population synthesis models, we analyze the variations of the SEDs as a function of radius. By studying the relationship between the stellar mass, star formation histories, star formation and HI gas, we will discuss the possible star formation modes and the roles played by the stellar mass and gas in determining the star formation in dwarf irregular galaxies in general.

We gratefully acknowledge funding for this research from the National Science Foundation (AST-0707563).

147.14

Gas, Stars, and Star Formation in Extreme Outer Disks of Dwarf Galaxies

Deidre Ann Hunter¹, S. Oh², B. Elmegreen³

¹Lowell Obs., ²University of Cape Town, South Africa, ³IBM T.J. Watson Research Center. Exhibit Hall

We compare deep optical images, deep ultraviolet images obtained with GALEX, and HI interferometric maps of five dwarf irregular galaxies in order to examine star formation in their outer disks. The V-band surface photometry, which extends to 29-30 mag/arcsec-squared, averages the star formation activity over the past Gyr for on-going star formation. The GALEX ultraviolet data provides information on star formation over the past 200 Myrs. The HI maps and cubes yield information on the gas surface densities and kinematics. We deconvolve the ordered rotation from non-ordered motions of the gas and compare with the stellar populations.

This research has been funded by the Lowell Research Fund and by NASA/GALEX grant NNX08AL66G.

147.15

Broken Surface Brightness Profiles in Dwarf Galaxies

Kimberly A. Herrmann¹, D. A. Hunter¹, H. X. Zhang¹, LITTLE THINGS Team

¹Lowell Observatory.

Exhibit Hall

Recently it has been well shown that there are three different surface brightness profile types in spiral galaxies: (I) the minority, where the light falls off with a single exponential; (II) truncated, the majority, where the light falls off with one exponential to a break radius and then falls off more steeply; and (III) anti-truncated, where the light falls off with a more shallow exponential beyond the break radius. Additionally, Bakos, Trujillo, & Pohlen (2008) showed that each type has a characteristic color trend with respect to the break location. In dwarf disk galaxies, however, there is a fourth type which is perhaps a special Type II case: the light profile is flat on the inside and then falls off exponentially beyond the break radius. We will show the different color trends for these four profile types from a large photometric study of dwarf disk galaxies and explore the ramifications of the differences between spirals and dwarfs.

We gratefully acknowledge funding for this research from the National Science Foundation (AST-0707563).

Spectroscopic Properties of Newly Discovered Ha Dots

Jesse Feddersen¹, J. J. Salzer¹, A. Williams¹, C. Gronwall² ¹Indiana University, ²Pennsylvania State University.

Exhibit Hall

We present newly discovered faint point sources of emission - called H α dots - found in narrow-band images taken for the ALFALFA H α project. These images target ALFALFA survey galaxies for the purpose of measuring their star-formation characteristics. Our image analysis turns up a large population of serendipitously discovered emission-line sources that are not associated with the target ALFALFA galaxy. In addition to presenting several dozen new objects, we have acquired and reduced spectral data for nearly all of the sample. These spectra reveal a mix of isolated extragalactic HII regions, ultra-low luminosity dwarf galaxies, background (higher redshift) galaxies, and QSOs. We present examples of several H α dots along with their follow-up spectroscopy, and give a summary of the properties of the full sample of H α dots discovered to date. We also illustrate why these objects are of astrophysical interest. For example, this selection method appears to provide a rich sample of nearby, very low metallicity dwarf systems, as well as luminous [O III]-detected star-forming galaxies at z ~ 0.32 with unusually low abundances.

147.17

The Detectability of Stealth Galaxies

Maya Barlev¹, B. Willman¹, R. Fadely¹ ¹*Haverford College.*

Exhibit Hall

The 2008 discovery of dwarf galaxy And XIX ($M_v = -9.3$, $r_h \sim 1.7$ kpc) around M31 raised the question of whether such large scale size systems could exist around the Milky Way but have evaded previous searches. Since then, the existence of yet-unseen "stealth" galaxies around the Milky Way - dwarfs with larger scale sizes and lower surface brightnesses than those currently known - has independently been predicted as a way to understand the apparent common mass scale of dwarf galaxies. To quantify the unexplored stealth galaxy parameter space around the Milky Way, we investigate the detectability of large scale length ($r_h > 1$ kpc) dwarf galaxies in the Sloan Digital Sky Survey dataset. We do this by i) simulating dwarf galaxies based on a Dotter isochrone of an old, metal-poor stellar population, ii) inserting simulated galaxies into the SDSS point source catalog, and iii) applying a standard search algorithm to the resulting catalog.

148 *Elliptical Galaxies* Poster Session *Exhibit Hall*

148.01

The Dynamical State of the Telescopium Galaxy Group - Deep Chandra Observations of NGC 6868 and NGC 6861

Kimberly Ward-Duong¹, S. W. Randall², M. E. Machacek²

¹Northern Arizona University, ²Harvard-Smithsonian Center for Astrophysics. Exhibit Hall

We present results from deep Chandra observations of NGC 6868 and NGC 6861, the two dominant elliptical galaxies in the Telescopium galaxy group (Abell S0851). We examine the diffuse gas in and around these galaxies to establish the possible interactions occurring within the group. Surface brightness images exhibit bright edges and tails, which indicate that the galaxy group is not dynamically

relaxed. Spectral analysis reveals a spiral of cool gas with an associated cold front edge in NGC 6868, indicative of gas sloshing initiated by a passing galaxy or subgroup. NGC 6861 shows bright, swept back arms and a broad tail of emission, both to the northwest, suggesting that it is being ram pressure stripped due to interactions with a diffuse intracluster medium as it moves to the southeast. We find evidence that the arms are composed of cool gas originating from the galaxy core, and propose that, as seen in other systems, they may be filaments that have been buoyantly lifted by putative radio lobes inflated by the central AGN. Our results are consistent with previous suggestions that NGC 6868 and NGC 6861 are the central dominant members of two distinct subgroups, which are currently merging to form the Telescopium galaxy group. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 0754568, by Chandra grant GO0-1009X issued under NASA contract NAS8-03060, and by the Smithsonian Institution.

148.02

Hi Content Of X-ray Faint Early Type Galaxies And Its Influence On Abundance

Yuanyuan Su¹, J. Irwin¹

¹University of Alabama.

Exhibit Hall

There is a growing body of evidence suggesting that field elliptical galaxies have larger HI halos around them, while elliptical galaxies near the centers of clusters have had their HI haloes destroyed. We compared galaxies with comparable low X-ray gas luminosity, some with HI haloes and some lacking HI haloes with Chandra, XMM and Suzaku archived observations. We found that galaxies with HI haloes (e.g. NGC 4278) has a low abundance for hot gas, while galaxies lacking HI haloes (e.g. NGC 4382) have high abundance for hot gas. We therefore interpret the measured very low abundance of X-ray faint galaxies as a result from the dilution of the remaining hot gas by this pristine HI gas.

148.03

Ionized Gas in E/S0 Galaxies with Dust Lanes

Jose G. Funes, S.J.¹, I. Finkelman², N. Borsch², P. Vaisanen³, A. Kniazev³

¹Specola Vaticana, Italy, ²The Wise Observatory and the School of Physics and Astronomy, Israel, ³South African Astronomical Observatory, South Africa.

Exhibit Hall

We present results from an ongoing program to study the properties of dust and ionized gas in E/S0 galaxies with dust lanes. Our observational program comprises of H-alpha and broad-band images obtained with the SAAO 1.9m, the VATT 1.8m and the 1m telescope on WO.

A detailed analysis of 30 galaxies shows the presence of a diffusely distributed ionized gas component in most objects. The extended gas morphology is typically smooth and closely follows the dust structure, with a clear correlation between the mass of both components. The dust content in each galaxy is estimated by measuring the extinction by the extragalactic dust in the dark lanes. The derived extinction law is used to correct the measured colors for intrinsic dust extinction and the data are fitted with a stellar population synthesis model. We find that the line-emission and colors of most objects are consistent with the presence of an "old" stellar population (~10 Gyr) and a small fraction of a "young" population (~10 Myr).

The younger stellar population may have formed at a later stage of the evolution of the galaxy through either a merger event or a secondary star-formation burst. Strong evidence for the external origin of the ISM is provided by the apparent inclination of the dust and ionized gas disks with respect to the galactic plane in a large fraction of our sample galaxies. Further spectroscopic observations will be obtained to study the gaseous disks dynamics and to characterize the underlying stellar populations for evidence of multiple phases of star formation and assembly history.

148.04 Gas Accretion in the M32 Nucleus: Past & Present Anil Seth¹

¹Harvard-Smithsonian CfA.

Exhibit Hall

Using adaptive optics assisted Gemini/NIFS data, I study the present and past gas accretion in the central 3" of the M32 nucleus. From changes in the spectral slope and CO line depths near the center, I find evidence for unresolved dust emission resulting from BH accretion. With a luminosity of 2e38 ergs/s, this dust emission is the most luminous tracer of current BH accretion. These observations suggest that using high resolution infrared data to search for dust emission may be an effective way to detect other nearby, low luminosity BHs, such as those in globular clusters. I also examine the fossil evidence of gas accretion contained in the kinematics of the stars in the nucleus. The higher-order moments (h3 and h4) of the line-of-sight velocity distribution show patterns that are remarkably similar to those seen on larger scales in elliptical galaxies and in gas-rich merger simulations. The kinematics suggests the presence of two components in the M32 nucleus, a dominant disk overlying a pressure supported component. I suggest a scenario, in which the nuclear disk formed gradually from the stellar winds of stars in the bulge of M32, that may provide a good explanation of the observed kinematics, stellar populations and abundance gradients seen in the nucleus. The kinematic measurements presented here are the highest quality available for the nucleus of M32, and may be useful for any future dynamical models of this benchmark system.

148.05

Supermassive Black Hole Activity Within Local Early-type Galaxies

Brendan P. Miller¹, E. Gallo¹, T. Treu²

¹University of Michigan, ²University of California, Santa Barbara. Exhibit Hall

We report preliminary results from an ongoing Chandra survey of 100 field early-type galaxies. This project investigates the influence of environment upon supermassive black hole (SMBH) accretion within formally inactive galaxies. The volume-limited sample has been selected to be well-matched to the recently conducted AMUSE-Virgo survey, which studied SMBHs within cluster early-type galaxies. That work resulted in the detection of nuclear X-ray sources in 32/100 objects, establishing a firm lower limit of 24-34% to the SMBH occupation fraction of normal galaxies, and found the average Eddingtonscaled X-ray luminosity to be a decreasing function of SMBH mass, evidence for accretion "downsizing" (Gallo et al. 2008, 2010). Galaxies in more isolated environments have distinct properties that might influence the rate of SMBH fueling. Relative to cluster sources, field early-type galaxies have a lower probability of mergers; they also likely retain a larger fraction of hot gas (due to reduced ram-pressure stripping) and apparently contain more cold gas and tend to have younger stellar populations. The X-ray detection fraction of the field early-type galaxies is found to be comparable to that of the AMUSE-Virgo survey. We correlate the average Eddington-scaled X-ray luminosity with SMBH mass for the observed objects and compare the relation to that found for cluster galaxies. We also calculate the rate of offnuclear X-ray sources and discuss implications for X-ray binary populations within field early-type galaxies.

Components of GALEX-Detected Star Formation in and around E and SO Galaxies

Lea Zernow¹, J. Ryon², B. F. Madore¹, M. Seibert¹, D. Neill³

¹Carnegie Observatories, ²University of Wisconsin - Madison, ³California Institute of Technology. Exhibit Hall

We present the first results of an investigation into ongoing star formation within E and S0 galaxies, selected from optical catalogs to be on the red sequence. Star formation in these spheroidal systems is traced using ultraviolet imaging from GALEX. We have identified a wide variety of unanticipated sites of apparent star formation in this sample, which include clumps, rings, and other structures. In order to quantify the contributions of these structures to the total UV flux, we have fit Sersic and/or exponential disk profiles to a subsample of 500 galaxies with high S/N, and compared the residuals of these smooth component fits to the original galaxy.

148.07

Star Formation in Brightest Cluster Galaxies

Aaron Scott Hoffer¹, M. Donahue¹, A. Hicks¹, R. Barthelemy¹

¹Michigan State University.

Exhibit Hall

We present Spitzer and GALEX spectral energy distributions (SEDs) for a sample of brightest cluster galaxies (BCGs). The BCG sample was selected from the Chandra archive, to have uniformly and well-measured X-ray cluster gas profiles for temperature, density, and entropy (Cavagnolo et al. 2009). The galaxy SEDs include data from GALEX [124 galaxies], 2MASS [202 galaxies], and Spitzer IRAC [108 galaxies] and MIPS [83 galaxies]. These spectral energy distributions are fit to Siebenmorgen and Krügel (2006) starburst galaxy models in the IR and Groves et al. (2008) star formation models which span the IR through the UV, as well as an SED for an old stellar population. This sample provides a good baseline for the colors to expect from a quiescent BCG, since this sample includes BCGs that do not inhabit cool core clusters. We confirm the trend for BCGs in systems with low central hot gas entropy to have UV and mid-IR emission in excess over that expected from a quiescent BCG. We compare the star formation signatures in the BCGs with those from star-forming and starburst galaxies and find that their IR/UV ratios are similar to other star-forming galaxies, while their FUV-NUV colors might be somewhat bluer.

148.08

An Integral Field View of Early-Type Galaxies in the Coma Cluster

Nicholas Scott¹, R. Houghton¹, R. L. Davies¹, N. Thatte¹, M. Cappellari¹, F. Clarke¹, L. Fogarty¹, M. Tecza¹ ¹University of Oxford, United Kingdom.

Exhibit Hall

We present Integral Field Unit (IFU) observations of a sample of 14 early-type galaxies (ETGs) in the Coma Cluster with Oxford's Short Wavelength Integral Field specTrograph (SWIFT) on the 200" Hale Telescope at Palomar. SWIFT is an i- and z-band IFU with R ~2 Å (σ ~ 35kms-1). Our sample was selected to evenly sample the full range in velocity dispersions of giant ETGs in the cluster (90km/s to 400km/s). The observations were taken using the 0.235" scale giving a field of view of 11" x 22", covering most galaxies out to one Re. We extract stellar kinematics from the Calcium Triplet (CaT, observed at ~8800 Å) using pPXF (Cappellari & Emsellem, 2004) and present velocity and velocity dispersion maps for each of the galaxies in the sample. Using our IFU observations combined with SDSS and, where available, HST photometry we derive: Re, Ie, and σ e and from these determine the Fundamental Plane of Coma ETGs. In the near future, we plan to study the fast rotator/slow rotator ratio in Coma, one of the densest and richest local environments for ETGs, to compare with the latest results from the volume limited ALTAS3D survey which lacks such high densities.

149 *Galaxy Clusters* Poster Session *Exhibit Hall*

149.01

Population Analysis of Seyfert Galaxies in the Coma-Abell 1367 Supercluster

Megan Jones¹, E. Wilcots¹ ¹University of Wisconsin-Madison.

Exhibit Hall

We study the population galaxies in groups along the Coma- Abell 1367 supercluster to study the occurrence of Seyfert galaxies. Within this population, we identified ~5% of the galaxies as Seyferts and found that ~40% of the groups contain at least one Seyfert. Only a small fraction of groups contain more than one Seyfert. We report on the distribution of Seyfert galaxies as a function of environment across the supercluster and probe the characteristics of the population of groups that currently host at least one Seyfert. In particular we correlate the properties of the population of Seyferts galaxies with the HI content of groups as derived in the ALFALFA survey.

149.02

The Galaxy Alignment Effect in Abell 1689

Li-wei Hung¹, E. Bañados², R. De Propris³, M. J. West⁴

¹The Ohio State University, ²P. Universidad Católica de Chile, Chile, ³Cerro Tololo Inter-American Observatory, Chile, ⁴European Southern Observatory, Chile.

Exhibit Hall

We examined alignments for galaxies in the galaxy cluster Abell 1689 (z = 0.18) based on archival Hubble Space Telescope WFPC2 F606W and F814W images. The sources were extracted using SExtractor. We used distance from the color-magnitud relation (defined by the bright galaxies) as a proxy to select likely cluster members. We carried out a series of simulations with artificial galaxies in order to understand the limit of our position angle measurement. Based on the cluster member selection and the result of our simulations, we isolated a sample of galaxies lying on the red sequence with I < 24 and e > 0.2 to study the alignment effect. By applying the Kuiper test, we find evidence of alignment among faint galaxies and galaxies in the inner 500 kpc of the cluster. The best mechanism to produce this alignment result is tidal torquing. Akin to the Earth-Moon system, tidal effects would (re)create alignments between galaxies. Under the presence of the tidal field, fainter galaxies, especially in the center, will align themselves more rapidly than brighter galaxies.

149.03

Galaxy Alignment In Low-Redshift Abell Clusters

Wayne Barkhouse¹, M. Byrd¹, O. Lopez-Cruz²

¹Univ. of North Dakota, ²INAOE, Mexico.

Exhibit Hall

We present an analysis of the alignment effect of galaxies extracted from a sample of 57 low-redshift (0.04 < z < 0.20) Abell clusters. Galaxies have been selected with respect to their color, luminosity, and distance from the cluster center. We investigate possible correlations between the orientation of cluster galaxies and various properties of the host cluster (e.g., optical richness, BM-type, and X-ray luminosity). Understanding the relationship between cluster galaxies and their local environment, will help to uncover details about galaxy formation and evolution in these dense systems.

Power Spectrum Analysis of Faraday Rotation Measure in the Intracluster Medium Gary Foreman¹, P. Ricker¹

¹University of Illinois, Urbana-Champaign.

Exhibit Hall

For conduction to be an efficient method for heating the cores of galaxy clusters, magnetic fields must be randomized within the central region of the intracluster medium (ICM). The heat-flux-driven buoyancy instability (HBI) tends to align magnetic fields azimuthally and shut off conduction; however, turbulence from mergers and galactic wakes may be enough to restore random orientations. One method for quantifying such randomness is through Faraday rotation measure mapping, which may be achieved using high resolution polarization measurements of the cosmic microwave background (CMB). In anticipation of such measurements, we present a statistical analysis of power spectra from numerically modeled rotation measure maps. We initialize a spherically symmetric galaxy cluster in hydrostatic equilibrium based on observed parameters of Abell 1060, and we generate rotation measure maps from randomly oriented, flux-frozen, divergence-free magnetic fields.

149.05

Evolution of the ICM Magnetic Fields from AGNs

Hao Xu¹, H. Li¹

¹Los Alamos National Lab.

Exhibit Hall

Radio observations suggested micro Gauss magnetic fields permeating the Intra Cluster Medium (ICM) in the galaxy clusters. Theory and simulations suggest that magnetic fields from Active Galactic Nucleus (AGNs) powered by their central super massive black holes can be an important source of these magnetic fields in the ICM. We present cosmological Adaptive Mesh Refinement (AMR) magnetohydrodynamic (MHD) simulations following the cluster formation and evolution of magnetic fields originally injected by AGN. We have performed simulations of a suite of galaxy clusters with virial masses ranging from 1×10^{14} to 2×10^{15} M $_{\odot}$. In most clusters, the injected magnetic fields can be transported throughout the whole cluster and be further amplified by the ICM turbulence to micro Gauss level. The magnetic field strength and total energy are dependent on the sizes of the clusters, while the amplification processes of the magnetic fields are determined by the cluster merger history. We will demonstrate how the ICM MHD turbulence is excited and sustained by the frequent mergers during the cluster formation. We will discuss the small-scale dynamo processes and their relations to the ICM turbulence in different clusters. We will also present the distributions of magnetic fields and Synthetic Faraday rotation measurement (FRM) of our simulated clusters.

This work was supported by the DOE/OFES via the Center for Magnetic Self-Organization and the LDRD program at LANL.

149.06

Mid Infrared Selected AGN in Galaxy Clusters From 0 < z < 1.2

Adam Tomczak¹, K. Vy-Tran¹, A. Saintonge²

¹Texas A&M University, ²University of Zurich, Switzerland. Exhibit Hall

We conduct a mid-infrared census of nine galaxy clusters with a total of 1517 spectroscopically confirmed member galaxies. Mid-IR color selection techniques were applied to identify active galactic nuclei (AGN) using *Spitzer* IRAC photometry. We find 12 candidate IR-AGN from a total of 712 cluster galaxies that have $\geq 3\sigma$ detections in all IRAC channels. To compare AGN activity across our redshift range we select three types of complete samples of galaxies: (1) galaxies with rest-frame [3.6]µm luminosity >1.3 × 10⁴⁴ erg s⁻¹, (2) a sample of the 100 brightest [3.6]µm galaxies and (3) galaxies with absolute V_{AB} magnitude <-21.5. For all three samples we observe a tendency for the fraction of IR-AGN in cluster galaxies (f_{AGN}) to increase with redshift. We observe the most rapid change between $z \approx 1.2$ and 0.8 where f_{AGN} drops from ~15±8% to ~3±2%, a time-span of ~1.5 Gyr. In general we find $f_{AGN} \approx 1\pm1\%$ at z < 0.7 but at z > 0.7 we calculate $f_{AGN} \approx 5\pm2\%$. The mid infrared AGN fraction for field galaxies in the *Spitzer* Extragalactic First Look Survey(XFLS) is ~7±1% at z < 0.7 for galaxies with [3.6]µm ≥ 100 µJy. In agreement with recent studies, we find that IR-AGN are predominantly hosted by late-type galaxies that preferentially occupy the blue-cloud. We further observe that the most luminous IR-AGN from our sample (a) are accompanied by X-ray emission, (b) are located ≥0.5 Mpc from the cluster center and (c) appear highly morphologically disturbed. These results support a scenario where X-ray-luminous AGN likely result from interactions/mergers of galaxies during infall into the cluster potential, simultaneously boosting the mid-IR signature.

149.07

Measuring the Effects of AGN Activity on the Intergalactic Medium

Hanna Herbst¹, K. Hess¹, E. Wilcots¹

¹UW Madison Astronomy Dept..

Exhibit Hall

Our current understanding of the formation and evolution of galaxy groups and clusters is impeded by a major problem. Models of gravitational collapse predict that the cores of galaxy groups should have had sufficient time to cool, but no observations have shown evidence of the cool gas that should reside in the cores. This means there must be some source of non-gravitational energy that is heating the intergalactic medium (IGM) and hindering the cooling flows. The two most likely sources are starburst driven galactic outflows or galactic outflows from active galactic nuclei (AGN). Here, we study AGN powered galactic outflows in NGC 1052 and NGC 741 as a possible source of the excess non-gravitational heating seen in x-ray observations. VLA data is used to estimate the total output of the radio jets, which is then compared the observed x-ray luminosity of the IGM, in order to determine to what extent AGN outflows could be responsible for the heating of the IGM.

149.08

Brightest Cluster Galaxy Identification

Luke Leisman¹, D. B. Haarsma¹, D. A. Sebald¹, ACCEPT team

¹Calvin College.

Exhibit Hall

Brightest cluster galaxies (BCGs) play an important role in several fields of astronomical research. The literature includes many different methods and criteria for identifying the BCG in the cluster, such as choosing the brightest galaxy, the galaxy nearest the X-ray peak, or the galaxy with the most extended profile. Here we examine a sample of 75 clusters from the Archive of Chandra Cluster Entropy Profile Tables (ACCEPT) and the Sloan Digital Sky Survey (SDSS), measuring masked magnitudes and profiles for BCG candidates in each cluster. We first identified galaxies by hand; in 15% of clusters at least one team member selected a different galaxy than the others.We also applied 6 other identification methods to the ACCEPT sample; in 30% of clusters at least one of these methods selected a different galaxy than the other methods. We then developed an algorithm that weighs brightness, profile, and proximity to the X-ray peak and centroid. This algorithm incorporates the advantages of by-hand identification (weighing multiple properties) and automated selection (repeatable and consistent). The BCG population chosen by the algorithm is more uniform in its properties than populations selected by other methods, particularly in the relation between absolute magnitude (a proxy for galaxy mass) and average gas temperature (a proxy for cluster mass).

This work supported by a Barry M. Goldwater Scholarship and a Sid Jansma Summer Research Fellowship.

149.09

The Hoag's Object, UGC 4599 and NGC 6028: Other Examples of Star Forming Rings Shannon MacKenzie¹, A. Pipino², R. Rich², C. Martin³, GALEX Team

¹University of Louisville, ²University of California Los Angeles, ³California Institute of Technology. Exhibit Hall

We study a sub-sample of Brightest Cluster Galaxies (BCGs) drawn from the Szabo et al. SDSS cluster catalogue, by selecting those in the richest clusters which also have a Galex counterpart and are at redshifts 0.1-0.4. Our multiwavelength approach allows us

to study recent episodes of star formation witnessed by the UV-optical colours, as a function of the host cluster properties. In particular, we present a sample of blue BCGs in likely cool-core clusters that deserve X-ray follow-up. The properties of these galaxies have been carefully compared to our control sample of blue BCGs which have a known X-ray counterpart.

Finally, we highlight the presence of interacting blue central early-type BCGs as interesting evidence of the

creation of the dominat galaxy. In the course of the survey of BCG star formation, we serendipitously discovered a new example of a UV ring galaxy, UGC 4599. We compare the UV properties of this new UV ring galaxy with the well studied elliptical NGC 404, and with Hoag's Object, for which we report the first GALEX photometry.

149.10

Uncovering The Nature Of Optically-faint Chandra X-ray Clusters

Stephanie Corbett¹, W. Barkhouse¹, P. Green², M. Smith³, A. Vikhlinin², D. Kim²

¹University of North Dakota, ²Harvard-Smithsonian Center for Astrophysics, ³Cerro Tololo Inter-American Observatory, Chile.

Exhibit Hall

We present analysis of infrared observations of eight extended Chandra X-ray sources that were serendipitously discovered as part of the Chandra Multiwavelength Project (ChaMP). These X-ray sources were selected as having no optical counterparts in NOAO 4-meter observations in gri passbands (limiting depth i~23.5). Since these ``X-ray only" clusters are likely to be at high redshift, we have acquired J- and Ks-band imaging of these objects using PANIC on the Magellan telescope. Our Magellan/PANIC data allows us to confirm the high redshift nature of our sample by measuring the cluster red sequence, and ascertaining the properties of galaxies in these distant systems.

149.11

Evolution Or Selection: The X-ray Properties Of Moderate-redshift Optically-selected Clusters Of Galaxies

Amalia K. Hicks¹

¹*Michigan State University. Exhibit Hall*

By virtue of their size, galaxy clusters can be used to place important constraints on cosmological parameters. In particular, charting the evolution of the cluster mass function provides us with vital information on the progression of large-scale structure formation over time. The masses of clusters, however, are often inferred from observables such as gas temperature or X-ray luminosity, which can be influenced by non-gravitational processes that affect cluster baryons, such as energy injection (heating) and radiative cooling. In addition, many high-redshift cluster surveys select samples based on baryon observables such as gas density. Recent correlations between temperature, luminosity, and total cluster

mass indicate significant discrepancies between observations and the theoretical expectations of selfsimilarity. Therefore understanding changes in cluster properties with redshift is of crucial importance to surveys that intend to use the evolution of the cluster population as a proxy for cosmic evolution, and ultimately for the determination of cosmological parameters. The results of our X-ray investigation of 13 high-redshift (0.6 < z < 1.1) optically-selected clusters suggest that the central entropy of these objects has been elevated by processes such as pre-heating, mergers, and episodic AGN outbursts, and that their ratio of gas mass to total gravitating mass is systematically lower than that found in lowerredshift X-ray selected clusters. To determine whether these effects are primarily associated with selection or evolution, we have designed a comparison sample of 10 moderate-z (0.2 < z < 0.6) optically-selected clusters, all of which have recently been observed by Chandra, Suzaku, or XMM. Here we present our final results from these observations, and discuss their relevance to cluster surveys which rely on the assumption of constant gas mass fraction to detect clusters and/or determine their masses.

149.12

Optical Scaling Relations of X-ray Selected Clusters at Moderate Redshift

Dylan Kloster¹, K. Rines¹, B. E. Svoboda¹, R. L. Arnold¹, T. J. Welch², R. A. Finn³, A. Vikhlinin⁴ ¹Western Washington University, ²McGill, Canada, ³Siena, ⁴CfA/IKI. Exhibit Hall

The relation between dark matter and galaxies is a fundamental problem in astrophysics. Here, we study this relation using optical observations of an X-ray-selected sample of clusters at moderate redshift (z=0.35-0.90). We collected griz images of 30 clusters with WIYN/OPTIC to measure the bright end of the luminosity function. Our imaging extends approximately 2 magnitudes fainter than M*, thus including most of the total cluster light. We use the red sequence and statistical background subtraction to estimate the richnesses and stellar luminosities of the clusters. We measure scaling relations by comparing the optical properties to X-ray mass estimates derived from Chandra observations. At low redshift, some studies indicate that total stellar luminosity is a better predictor of cluster mass than X-ray luminosity. We test whether a similar result holds at moderate redshift. In the future, we will compare the optical and X-ray properties to virial mass estimates from optical spectroscopy and to Sunyaev-Zeldovich Effect observations. If photometric properties of clusters are good predictors of cluster mass, these relations could be applied to large surveys like SPT, Planck, DES, eROSITA, and LSST to improve constraints on the properties of dark energy.

149.13

A Systematic Search For X-ray Cavities In Galaxy Clusters

Haik Manukian¹, R. Dong², J. Mulchaey³, J. Rasmussen⁴

¹UC Santa Cruz, ²Princeton, ³Carnegie, ⁴DARK Cosmology Centre, Denmark. Exhibit Hall

We have performed a systematic search for X-ray cavities in the hot gas of 280 galaxy clusters using Chandra archival data. The cavities are identified by subtracting an elliptical beta-model fitted to the Xray surface brightness. Standard data reduction and calibration was performed to the cluster data using the most recent version of CALDB. Exposure maps were computed for the clusters assuming a monoenergetic distribution of source photons at the peak flux energy (usually around 1keV). The source images were then normalized by the exposure map, correcting for the effect of strongly variable exposure near the detector edges. A beta-model was then fitted and a residual image was obtained. The residual images were then visually inspected for cavities. Finally, we modeled the cavities as ellipses. We find tight correlations between the radial and tangential radii of the cavities, and between their size and projected distance from the cluster center, in quantitative agreement with the case for groups. This suggests that similar physical processes are responsible for cavity evolution and disruption in systems covering a large range in total mass.

149.14

Shocks in Galaxy Cluster X-ray Temperature Images

Greg Salvesen¹, J. W. Henning¹, S. W. Skillman¹, J. O. Burns¹

¹University of Colorado.

Exhibit Hall

We present adaptively binned X-ray temperature maps for a sample of galaxy clusters created from joint spectral fitting to *XMM-Newton* and *Chandra* archival data. The overall distribution of temperature in a cluster is more tightly constrained for maps produced by joint fitting than from fits to individual spectra alone. Mach number distributions are generated from temperature gradients, providing insight into the magnitude of shocks within the cluster. Major mergers are expected to produce shock structure, tracing the formation history of galaxy clusters. Applying our shock finding method to simulated temperature maps created with the *Enzo N*-body + hydrodynamic adaptive mesh refinement cosmological code, we find that the underlying Mach number distribution is recovered from the temperature structure after applying our binning scheme. While the quality of temperature maps generated from joint spectral fitting strongly depends on reliable calibration between the different instruments, we find our method to be a promising probe of the temperature structure in cluster environments and potentially the merger history.

149.15

Measurement of the Temperature Distributions of Galaxy Clusters

Kari A. Frank¹, J. R. Peterson¹, K. Andersson², J. S. Sanders³, A. C. Fabian³ ¹*Purdue University*, ²*MIT*, ³*Univ. of Cambridge, United Kingdom. Exhibit Hall*

We utilize a Markov Chain Monte Carlo analysis to measure a new galaxy cluster parameter, the width of the ICM temperature distribution (σ_{logkT}), as well median temperature, emission measure, cluster size, and abundance. Critical to measuring σ_{logkT} , the MCMC avoids typical assumptions such as spherical symmetry and isothermality by modeling the ICM as a collection of X-ray emitting, smoothed particles of plasma, each with its own set of parameters including temperature, emission measure, position, and abundance. The resulting distribution of particle temperatures is then representative of the ICM temperature distribution, and similarly for the other parameters. The cluster temperature and σ_{logkT} are defined as the median and standard deviation of the temperature distribution, respectively. The cluster emission measure is simply the sum of the particle emission measures, and the characteristic cluster size is determined from the particle spatial positions. We have so far performed this analysis on XMM-Newton observations of 20 clusters with temperatures of 1keV-13keV in order to search for correlations between the temperature width and other cluster parameters.

149.16

Caustic Mass Estimate of Abell 370

Melodie Kao¹, C. Harrison²

¹Massachusetts Institute of Technology, ²University of Michigan. Exhibit Hall

As the largest virialised structures in the Universe, galaxy clusters are important tools for constraining cosmological models. In particular, cluster masses can be used to estimate the M/L of the Universe and from that the matter energy density, Omega_m. The most frequently used methods for estimating cluster masses are limited in their applicability. We present here a method of cluster mass estimation that is relatively free from these limitations. Originally proposed by Diaferio and Geller (1997), this method

uses the amplitude of the caustics formed by galaxies in redshift space to estimate the escape velocity of the cluster gravitational potential and therefore the cluster mass. We estimate the mass within $^{2}R_{vir}$ of the rich cluster A370 (at *z*=0.3745) using this method. We thank the CTIO 2010 REU Program for supporting this work.

149.17

The Faint End of the Galaxy Luminosity Function in A1689: A Steep Red Faint End Upturn at z = 0.18 Eduardo Banados¹, L. Hung², R. De Propris³, M. West⁴

¹Pontificia Universidad Catolica de Chile, Chile, ²Ohio State University, ³Cerro Tololo Inter-American Observatory, Chile, ⁴European Southern Observatory, Chile.

Exhibit Hall

We present a deep and wide I Luminosity Function (LF) for galaxies in Abell 1689 (z=0.183) from HST WFPC2 mosaic images covering 10' on the side. The main result of this work is the detection of a steep upturn in the dwarf galaxy LF, with a faint-end slope \sim -2. We show that the faint end upturn is dominated by red quiescent galaxies.

Evidence of luminosity segregation is presented: the dwarf-to-giant ratio appears to increase outward, but this is because giant galaxies are missing in the cluster outskirts.

It seems likely therefore that the fainter galaxies have not been accreted from the field at recent times.

149.18

Galaxy Evolution in Ten Nearby Clusters Through XMM-OM Ultraviolet Photometry

Neal A. Miller¹, S. Yen¹

¹University of Maryland.

Exhibit Hall

We report on a program capitalizing on the availability of XMM Optical Monitor(XMM-OM) ultraviolet (UV) photometry to study galaxy evolution in clusters. We have produced a sample of ten nearby Abell clusters with XMM-OM, SDSS, and GALEX photometry, including nearly 800 objects with SDSS spectra and XMM-OM UV photometry. Of these, over 500 are galaxies belonging to the parent cluster sample. We use this large database to explore color-magnitude relations and identify various classes of objects. We further demonstrate the application of XMM-OM UV photometry to evaluate the star formation histories of galaxies. Support for this work is provided by NASA Award Number NNX09AC76G.

149.19

Clg J0218.3-0510: New Results On The Most Distant Spectroscopically Confirmed Cluster

Ivelina G. Momcheva¹, C. Papovich², C. Willmer³, M. Pierre⁴, N. Clerc⁴, K. Tran², J. Lotz⁵, K. Finkelstein², S. Finkelstein², G. Rudnick⁶, P. McCarthy¹

¹Carnegie Observatories, ²Texas A&M University, ³University of Arizona, ⁴Service d Astrophysique du CEA, France, ⁵STScI, ⁶University of Kansas.

Exhibit Hall

CIG J0218.3-0510 at z=1.62 is currently the most distant spectroscopically confirmed cluster. We will present results based on new ground-based spectroscopy of this cluster complemented by Chandra X-ray Observatory observations. We will examine the star formation rates and nuclear activity of the cluster galaxies with a focus on the high concentration of LIRGs and ULIRGs found in the cluster core and discuss their effect on the X-ray emission from the cluster. We will also outline our continuing survey to identify and study other z>1.5 clusters.

Abundances in Spiral Galaxies of the Pegasus I Cluster

Paul Robertson¹, G. A. Shields¹, G. A. Blanc¹

¹University of Texas at Austin.

Exhibit Hall

We present a study of abundances in spiral galaxies of the Pegasus I cluster (cz = 4000 km/s), motivated by evidence for high interstellar abundances in the spirals of the Virgo cluster. Spectra of H II regions in six galaxies with a range of H I deficiency were obtained with the VIRUS-P integral field spectrograph on the 2.7-meter telescope at McDonald Observatory. The results suggest a pattern of higher abundances in more hydrogen deficient galaxies. This resembles the case for Virgo, despite the lower velocity dispersion and higher spiral fraction in the Pegasus cluster.

149.21

Specific Star Formation in the Abell 85 Cluster and its Filament

Dario Fadda¹, L. O. V. Edwards¹, F. Durret²

¹*Caltech*, ²*IAP*, *France*.

Exhibit Hall

We report the first results of the analysis of more than 500 optical spectra and near-infrared photometry targeting the galaxies of the Abell 85 cluster and its filament. Our team discovered the filament initially using X-ray observations. Recently, in order to study the dynamical and star formation properties, we have further supplemented our dataset with more than 500 new spectra covering cluster galaxies down to r'=21. We have also obtained J, H, and K images of approximately one square degree covering the cluster and its Southern filament. We present here a study of how the specific star formation, i.e. the star formation normalized by stellar mass, of the member galaxies varies in the different environments of the cluster: core, filament, and other external regions.

149.22

Gas-rich Optically Inert Galaxies in the Virgo Cluster

Brian R. Kent¹

¹NRAO.

Exhibit Hall

Aperture synthesis observations of two HI cloud complexes located in the periphery of the Virgo galaxy cluster are presented. These low HI-mass clouds (log(MHI) < 8 at 16.7 Mpc) are seen toward the western M region of Virgo, where the galaxy population is thought to lie behind the main A cluster surrounding M87. The kinematic measurements of both unresolved Arecibo and resolved VLA-C observations are in good agreement. The HI detections cannot be identified with any optical,IR, or UV emission from available archival imaging. They are inert at these wavelengths. The total dynamical mass estimates are several times their HI content. We report the observed parameters derived from the VLA observations. One of these detections appears to be the most isolated optically inert object observed in the outer reaches of Virgo.

149.23

Arecibo Galaxy Environment Survey Observations of the NGC 7448 Region and the HI Mass Function Robert F. Minchin¹, J. I. Davies², Arecibo Galaxy Environment Survey (AGES)

¹Arecibo Obs., ²Cardiff Univ., United Kingdom.

Exhibit Hall

The Arecibo Galaxy Environment Survey (AGES) is the deepest wide-area blind HI survey to date. Each surveyed region is centered on a nearby galaxy, group or cluster: we here report on the observations of the NGC 7448 group. Galaxy interactions in the NGC 7448 group reveal themselves through tidal tails

and bridges - we find approximately 2.5 times more atomic gas in the intragroup medium than in the group galaxies. We also identify five new dwarf galaxies, two of which appear to be members of the NGC 7448 group. This is too few dwarf galaxies to reconcile observations with theoretical predictions of galaxy formation models.

Combining the data from this group with observations of other AGES regions to derive an HI mass function which is well fit by a Schechter function with a relatively steep faint-end slope of -1.53 ± 0.5 . Integrating this mass function gives a cosmic mass density of neutral hydrogen of $8.9 \pm 0.8 \times 10^{-4}$ - twice that found in the ALFALFA survey and almost three times higher than found in HIPASS.

149.24

Globular Cluster Survey in the Shapley Supercluster

Regina Barber DeGraaff¹, J. P. Blakeslee², W. E. Harris³

¹Washington State University, ²Herzberg Institute of Astrophysics, Canada, ³McMaster University, Canada.

Exhibit Hall

We present a survey of the globular cluster systems of 11 giant elliptical galaxies in clusters associated with the Shapley Supercluster. The program galaxies were imaged with the ACS/WFC in the F814W bandpass (comparable to I-band) and are in the redshift range z = 0.035-0.046. Radial density plots and the total globular cluster populations of these 11 galaxies are presented. The most massive galaxy in our sample contains the largest globular cluster population studied to date. Another galaxy in our sample, ES0325-G004, is the nearest gravitational lensing galaxy, and STScI obtained multi-band imaging for a press release image. This provides additional color information on its rich GC system.

149.25

Searching for Intragroup Light in Multiple Galaxy Groups

John J. Feldmeier¹, S. Downing¹, J. C. Mihos², P. Harding², H. L. Morrison²

¹Youngstown State Univ., ²Case Western Reserve University.

Exhibit Hall

Intracluster stars, stars outside of galaxies, have been shown to be common in galaxy clusters, and contain approximately 20% of the total stellar luminosity. However, the amount of intragroup light in galaxy groups is substantially less certain. Estimates of the intragroup luminosity fraction range from 0% to 46% of the total light. This is extremely unfortunate, since the majority of galaxies are in groups, and theoretical work shows that the group environment can have strong effects on the production of intracluster/intragroup light.

Here, we give an update on our efforts to determine the amount and spatial distribution of intragroup light in both normal and compact groups. We will present data from the 0.6m Burrell Schmidt and the KPNO 2.1m of four Hickson and four normal galaxy groups, including the nearby Leo I group that is known to have intergalactic star formation. Using the techniques of deep surface photometry, we can reach faint surface brightnesses of 26-27 magnitudes per square arcsecond. We will show tidal features found in these groups, and provide estimates of the total intragroup fraction.

149.26

Using Networking Algorithms to Assess the Environment of Galaxy Groups

Ali Bramson¹, E. M. Wilcots¹

¹University of Wisconsin-Madison.

Exhibit Hall

Understanding the environment a galaxy resides in is crucial to our understanding of the galaxy's formation and properties. Most galaxies (~70%) live in groups and it is important to develop a quantitative understanding of how galaxies are distributed within groups and how groups are

distributed in the larger scale structure. In addition to the traditional friends-of-friends algorithms we are applying analytical techniques developed for understanding social networks to understand the network of galaxies in the Abell 1367-Coma supercluster. We use data from the SDSS, 2MASS, and ALFALFA to detect substructure within catalog groups and quantitatively measure the degree to which individual groups are connected as a new method of probing the large scale environments of galaxies and groups.

149.27

The Mysterious Cheshire Cat Galaxy System. The First Case of a Collision Between Fossil Groups? Jimmy Irwin¹, R. Dupke²

¹Univ. Of Alabama, ²Univ. Of Michigan. Exhibit Hall

Fossil groups present a puzzle to current theories of structure formation. Despite the low number of bright galaxies, their high velocity dispersions and high gas temperatures seem to indicate cluster-like gravitational potentials. One extreme example of a potential fossil group is the Cheshire Cat gravitational lens group of galaxies. While it contains two bright central galaxies rather than one (surrounded by ~25 galaxies at least two magnitudes fainter), these galaxies are moving at least 1100 km/s relative to one another and likely represent the collision of TWO fossil groups. We analyzed data from a moderately long Chandra observation of the Cheshire Cat and found and found the ICM to have a very hot (~6 keV) core, but a low X-ray luminosity, which places it off the L_X/T_X relation for groups/clusters. Furthermore, the X-ray emission does not appear to be centered on either bright galaxy, but midway between them. We discuss the implications of the Chandra results and discuss whether this system represents the first example of a fossil-group/fossil group merger.

149.28

SMARTS H α Observations Of ALFALFA Gas-rich Galaxies In NGC 5846

Katelyn M. O'Brien¹, R. A. Koopmann¹, ALFALFA Team

¹Union College.

Exhibit Hall

The Undergraduate ALFALFA (Arecibo Legacy Fast ALFA) Team Groups Project is a collaborative undertaking of faculty and undergraduates at 11 institutions, aimed at investigating properties of galaxy groups surveyed by the ALFALFA blind HI survey. The Union College team is analyzing the galaxy group NGC 5846 and its environments. Here we present star formation properties of 12 gas-rich galaxies in the group as traced by CCD H α images obtained at the Small and Moderate Aperture Research Telescope System (SMARTS) CTIO 0.9m telescope. This work has been supported by NSF grants AST-0724918, AST-0725267, and AST-0725380.

149.29

HI Deficiency as a Function of Galaxy Type in the MKW11 Group

James Turner¹, M. Crone-Odekon¹, ALFALFA Team

¹Skidmore College.

Exhibit Hall

The Undergraduate ALFALFA (Arecibo Legacy Fast ALFA) Team Groups Project is a collaborative undertaking of faculty and undergraduates at 11 institutions, aimed at investigating properties of galaxy groups surveyed by the ALFALFA blind HI survey. As part of this project we examine a 10x10 degree region around the rich galaxy group MKW 11 in order to study HI deficiency as a function of local density as well as optical galaxy morphology. Our sample includes 496 galaxies in the Sloan Digital Sky Survey, 153 of which are detected in HI. This work has been supported by NSF grants AST-0724918, AST-0725267, and AST-0725380.

149.30 Group Membership and HI Sources in the WBL 368 Galaxy Group **Catherine Weigel**¹, M. Brault¹, P. Troischt¹, ALFALFA Team

¹Hartwick College.

Exhibit Hall

The Undergraduate ALFALFA (Arecibo Legacy Fast ALFA) Team Groups Project is a collaborative undertaking of faculty and undergraduates at 18 institutions, aimed at investigating properties of galaxy groups surveyed by the ALFALFA blind HI survey. The Hartwick College team is analyzing a 6X6 degree region around the galaxy group WBL 368, which has an average recessional velocity of 4732 km/s. Preliminary analysis using ALFALFA data and the Sloan Digital Sky Survey indicates a significant increase in group membership, with 47% of the member galaxies detected as HI sources. This work has been supported by NSF grants AST-0724918, AST-0725267 and AST-0725380.

149.31

Stellar Populations and Star Formation of ALFALFA Galaxies in Coma-Abel 1367

Cody Gerhartz¹, M. Jones¹, K. Hess¹, E. Wilcots¹

¹University Of Wisconsin Madison.

Exhibit Hall

We present GALEX near-ultraviolet (NUV) and far-ultraviolet (FUV) photometry, Sloan Digital Sky Survey r and u-band photometry, as well as archival 2MASS observations for the Coma-Abell 1367 Supercluster. Our aim is to study the stellar populations and star formation history of HI-detected galaxies from the ALFALFA survey. We correct for the effects of interstellar reddening and inclination on the observed uv colors and derive an measure of the rate of recent and current star formation, and how they are linked to the HI content, of galaxies throughout the supercluster.

150 Large Scale Structure, Cosmic Distance Scale **Poster Session** Exhibit Hall

150.01 **RR Lyrae as Structural Tracers for the LMC** Katherine Accetta¹, A. Kunder²

¹Youngstown State University, ²CTIO, Chile. Exhibit Hall

RR Lyrae variable stars are key distance indicators because they have a predictable period-luminosity relation. Previous surveys by the OGLE and MACHO collaborations have identified RR Lyrae stars within the Large Magellanic Cloud (LMC), but as the prime directive of these surveys was to search for gravitational lensing effects, precision photometry was not a primary concern. We have obtained accurate V and R photometry of a sub-sample of OGLE RR Lyrae located around the central bar. The results presented here encompass two of the twenty-six surveyed fields, one field on the far east side of the central bar and the other on the far west. Distances and reddening along the line of sight of 50 RR Lyrae can be used to map out the structure of the old stellar populations within the LMC. A comparison on the properties of the RR Lyrae in these two fields allow constraints to be made on the orientation of the LMC, and to place limits on the warping of the LMC disk.

The Flow-field From Galaxy Groups In 2MASS

Aidan Crook¹, J. Huchra², L. Macri³, K. Masters⁴, T. Jarrett⁵

¹Microsoft, ²Harvard-Smithsonian Center for Astrophysics, ³Texas A&M University, ⁴University of Portsmouth, United Kingdom, ⁵California Institute of Technology. Exhibit Hall

We present the first model of a flow-field in the nearby Universe (cz < 12,000 km/s) constructed from groups of galaxies identified in an all-sky flux-limited survey. The Two Micron All-Sky Redshift Survey (2MRS), upon which the model is based, represents the most complete survey of its class and, with near-IR fluxes, provides the optimal method for tracing baryonic matter in the nearby Universe.

Peculiar velocities are reconstructed self-consistently with a density-field based upon groups identified in the 2MRS K_s <11.75 catalog. The model predicts infall toward Virgo, Perseus-Pisces, Hydra-Centaurus, Norma, Coma, Shapley and Hercules, and most notably predicts backside-infall into the Norma Cluster. We discuss the application of the model as a predictor of galaxy distances using only angular position and redshift measurements.

By calibrating the model using measured distances to galaxies inside 3000 km/s, we show that, for a randomly-sampled 2MRS galaxy, improvement in the estimated distance over the application of Hubble's law is expected to be ~30%, and considerably better in the proximity of clusters. We test the model using distance estimates from the *SFI++* sample, and find evidence for improvement over the application of Hubble's law to galaxies inside 4000 km/s, although the performance varies depending on the location of the target.

This work has been supported by NSF grant AST 0406906 and the Massachusetts Institute of Technology Bruno Rossi and Whiteman Fellowships.

150.03

21 Cm Tomography With the Alfalfa Survey

Alexander B. Fry¹, C. Boutan¹, P. A. Carroll¹, B. Hazelton¹, M. F. Morales¹

¹University of Washington.

Exhibit Hall

Neutral hydrogen (HI) 21cm intensity mapping, or HI tomography is a promising technique being utilized by several upcoming experiments (LOFAR, MWA, SKA). The measurement of volume averaged neutral hydrogen mass density in synoptic sky surveys can be applied to the study of the HI mass function, the distribution of large scale structure, the reionization of the universe, and the expansion history of the universe through such standard rulers as baryonic acoustic oscillations. In order to prepare for future experiments, in particular the Murchison Widefield Array (MWA), we analyze the Arecbo Legacy Fast ALFA (Arecibo L-Band Feed Array) Feed Array (ALFALFA) survey data to probe the spatial density variations of HI in our local universe (z <0.06) where data is currently available. We address challenges unique to data of this kind, such as identifying and subtracting out signal from RFI and local galactic sources, and characterizing the ALFA array beam pattern which dictates sensitivity and resolution.

150.04

Estimating Photometric Redshifts in Non-Representative Galaxy Samples using Boosted Decisions Trees

Adam J. Sypniewski¹, D. W. Gerdes¹

¹University of Michigan.

Exhibit Hall

Future large-scale optical surveys, such as the Dark Energy Survey, will require photometric redshift estimates for hundreds of millions of galaxies. In general, the magnitude and color distributions of these

galaxies are expected to differ from those of the spectroscopic sets used for training empirically-based photometric redshift algorithms. In this analysis, we investigate the robustness of the ArborZ boosted decision tree method for estimating photometric redshifts in these non-representative cases. We show that ArborZ performs well in these cases, provided that the training and target sets have sufficient overlap in parameter space. We also compare the results of training ArborZ on magnitudes, colors, and a combination of the two.

150.05

Photometric Redshift Catalog of SDSS DR8 Luminous Red Galaxies

Antonio Jose Cuesta-Vazquez¹, A. Ross², S. Ho³, N. Padmanabhan¹, F. Prada⁴, M. White⁵, D. J. Schlegel³, W. J. Percival², N. Connolly⁶, F. de Simoni⁷, B. Ramos⁷, N. Ross³, L. A. N. da Costa⁷

¹Yale University, ²Institute of Cosmology and Gravitation, University of Portsmouth, United Kingdom, ³Lawrence Berkeley National Laboratory, ⁴Instituto de Astrofisica de Andalucia, Spain, ⁵University of California at Berkeley, ⁶Hamilton College, ⁷Observatorio Nacional, Brazil. Exhibit Hall

The project focuses on the calibration of photometric redshifts of luminous red galaxies within the DR8 imaging catalog of Sloan Digital Sky Survey. We aim to use the spectroscopic sample of BOSS galaxies and compare their (true) spectroscopic redshifts with photometric redshifts obtained from different techniques. We discuss the performance of photo-z estimation via template fitting of the spectral energy distribution and trained neural networks using ANNz. We also obtain the photometric redshift distributions of luminous red galaxies in different redshift bins and provide an analytical fit to these distributions. In this sense, we comment on the capabilities of ANNz to investigate the systematics involved in galaxy clustering measurements, such as spatial variations of the redshift distributions. The resulting photo-z catalogs are useful for the estimation of cosmological parameters through the evaluation of the power spectrum (Padmanabhan et al. 2007), which will benefit from large sky area covered by SDSS-III imaging sample.

151

Dark Matter & Dark Energy Poster Session *Exhibit Hall*

151.01

Monte Carlo approach to Dark Matter Mapping Suzanne Lorenz¹, J. R. Peterson¹ ¹Purdue University.

Exhibit Hall

We present an an analysis method of constructing dark matter maps based on weak lensing using a Markov Chain Monte Carlo technique. The dark matter in a cluster can be modeled as a collection of massive blobs that bend light according to gravitational lensing. We move these dark matter blobs in RA, Dec and redshift and as a result perturb the ellipticities of subsequent background galaxies. With this method we have looked at images of Abell 2218 from the Subaru archive, which have been analyzed by our wavelet source detection algorithm and all the ellipticities calculated using second moments. From this we have been able to reconstruct a mass map. With the ability to reconstruct dark matter distributions in redshift as well as projected on the sky, we may be able to more accurately reconstruct the dark matter web.

151.02 Galaxy Kinematics with VIRUS-P: The Dark Matter Halo of M87 Jeremy Murphy¹, K. Gebhardt¹, J. J. Adams¹

¹University of Texas, Austin.

Exhibit Hall

We have conducted axisymmetric, orbit-based dynamical modeling on M87, the second rank galaxy in the Virgo cluster, and find clear evidence for a large dark matter halo. The total enclosed mass within 47 kpc is 6e12 solar masses making M87 one of the most massive dark halos ever measured in the local universe. To construct these dynamical models we fit for the stellar mass-to-light ratio and two dark halo parameters, assuming a cored logarithmic dark halo profile. The dynamical data comes from existing globular cluster data, SAURON stellar kinematics in the center of M87, and new 2-D stellar kinematics taken with VIRUS-P, an integral field unit currently deployed at the McDonald Observatory. These kinematics add significantly to the current data set on M87 and allow for a direct comparison between different dynamical tracers. We find good agreement between the dynamics of the stars and globular cluster data at large radii, indicating these two systems are in equilibrium. However, the enclosed mass we measure is 60% higher than recent mass estimates calculated from X-ray gas measurements. Understanding the systematics present in the various tools used to estimate mass in local galaxies is critical to our understanding of the formation history and the role dark matter plays in the evolution of these galaxies.

We also report on the current status of a VIRUS-P survey of the stellar kinematics of local, massive elliptical galaxies. Our data set includes giant field ellipticals, cluster members and brightest cluster galaxies. The goal of this project is to quantify the amount of dark matter in these systems in order to explore how the role of cluster environment influences both the amount and shape of the dark matter profile.

151.03

A Search for Dark Matter Decay Products in Nearby Dwarf Galaxies

Bang Nhan¹, B. Mason², K. Spekkens³, J. Aguirre⁴

¹University of Colorado at Boulder, ²National Radio Astronomy Observatory, ³Royal Military College of Canada, Canada, ⁴University of Pennsylvania.

Exhibit Hall

According to the current cosmological concordance model, 23% of the universe's denisty is consisted of cold dark matter (CDM). One of the candidates for the CDM is Weakly Interacting Massive Particle (WIMP). Supersymmetric (SUSY) extension of the Standard Model of particle physics has predicted a stable and electrically neutral particle with rest mass between 1 GeV and 1000 GeV. It is known as the neutralino. Colafrancesco et al. (2007) proposes possible indirect detection of the neutralino through decay products of its self annihilation in nearby dwarf spheroidal (dSph) galaxies. We have used Green Bank Telescope (GBT) to search for synchrotron radiation from the self annihilation in four sources: Draco, Ursa Major II, Willman 1, and Coma Berenices. We discuss the analysis of these data, present maps and radial profiles of these four dSph systems, and a comparison with theoretical predictions of the neutralino decay signature.

151.04 A New Assessment of Dark Matter in the Milky Way Galaxy Grant N. Remmen 1

¹University of Minnesota - Twin Cities.

Exhibit Hall

Through an examination of recent data on the mass distribution and velocity curve of the Milky Way Galaxy, I produce a new estimate of the dark matter distribution, as well as the overall dark matter content, of our galaxy. Initially, I develop a model of the baryonic mass of the galaxy (i.e. luminous matter and interstellar clouds). This model incorporates three components: an exponential stellar disc and a central stellar bulge, based on the Tuorla-Heidelberg model, and a gaseous layer, fit to the gas density distribution data of Olling & Merrifield (2001). Secondly, incorporating recent data, I calculate an updated rotational velocity curve for the galaxy as a function of galactocentric radius. Using this velocity curve, I determine total galactic mass as a function of radius and compare this with the baryonic mass model to determine the distribution of dark matter in the galaxy, with improved precision and over a greater spatial range than previous estimates. This calculation results in a radial dark matter density distribution that falls off with large distance in a characteristic fashion. Finally, I show that neutrinos, particles that have often been suggested as a component of dark matter, cannot make up more than a negligible fraction of the galactic dark matter content. Funding for this research was provided by the University of Minnesota College of Science & Engineering/Institute of Technology Honors Undergraduate Research Scholarship program.

151.05

Constraining Modified Gravity Theories with Cosmological Data

Scott Daniel¹, E. V. Linder²

¹University of Washington, ²Lawrence Berkeley National Laboratory. Exhibit Hall

Cosmic acceleration could be either an effect of dark energy or of a gravity theory other than General Relativity operating on cosmological scales. We constrain these competing possibilities by examining the growth of perturbations in both the Cosmic Microwave Background and large scale structure as measured by weak lensing surveys, galaxy counts, and galaxy-CMB cross-correlations. We consider a model-independent parametrization of departures from General Relativity and find that, while Newton's constant is constrained to be consistent with General Relativity to within a few 10%, a parameter modifying the growth rate of structure is largely unconstrained by present data. We do find evidence for departure from General Relativity at small scales and low redshifts. We believe, however, that this is due primarily to artifacts in the data and uncertainty in the behavior of non-General Relativity gravity theories at non-linear scales. This work was supported by the World Class University grant R32-2009-000-10130-0 through the National Research Foundation, Ministry of Education, Science and Technology of Korea.

151.06

3D Reconstruction of the Density Field: Using Redshift Information in Weak Lensing Analysis Jake Vander Plas¹, A. J. Connolly¹, B. Jain², M. Jarvis²

¹University of Washington, ²University of Pennsylvania. Exhibit Hall

We present a new method for constructing three-dimensional mass maps from gravitational lensing shear data. We solve the lensing inversion problem using truncation of singular values (within the context of generalized least squares estimation) without a priori assumptions about the statistical nature of the signal. This singular value framework allows a quantitative comparison between different

filtering methods: we evaluate our method beside the previously explored Wiener filter approaches. Our method yields near-optimal angular resolution of the lensing reconstruction and allows cluster sized halos to be de-blended robustly. It allows for mass reconstructions which are 2-3 orders-of-magnitude faster than the Wiener filter approach, which will become increasingly important for future large surveys, e.g. LSST. Using this SVD framework, we discuss optimal redshift binning for 3D shear mapping, and explore how this informs the choice of binning in measurements of power spectrum evolution.

152

Star Associations, Star Clusters - Galactic & Extra-galactic Poster Session *Exhibit Hall*

152.01

What Can 100 Million Monte Carlo Simulations Do For You? - Age and Mass for 900 LMC Clusters Margaret M. Hanson¹, B. Popescu¹

¹Univ. of Cincinnati.

Exhibit Hall

The new version of the MASSCLEAN*colors* database contains over 100 million cluster models. Presently, current models for stellar populations are available only in the *infinite mass limit*. But real clusters have a finite mass, and their integrated colors show a large dispersion due to stochastic fluctuations in the stellar mass function. The MASSCLEAN*colors* database illustrates the extreme and non-Gaussian distribution of integrated colors and magnitudes consistent with theoretical work and integrated photometry of real clusters. The database entries form a consistent set of integrated colors and magnitudes, age and mass and can be used to improve age and mass determinations of moderate mass stellar clusters. Our newest application, MASSCLEAN*age*, uses observed integrated UBVR photometry and a statistical inference code to search the MASSCLEAN*colors* database to solve simultaneously for the age and mass of a cluster. We demonstrate the power of MASSCLEAN*age* by presenting new values for age and mass for 900 LMC clusters. This material is based upon work supported by the National Science Foundation under Grant No. 0607497 & 1009550.

152.03

Color Selection of Intracluster Globular Clusters in the Next Generation Virgo Survey

Patrick R. Durrell¹, A. McConnachie², K. Accetta¹, E. W. Peng³, NGVS Team

¹Youngstown State Univ., ²HIA, Canada, ³Peking University, China. Exhibit Hall

The Next Generation Virgo Survey (NGVS) is a large, 104 square degree deep imaging survey (with CFHT's MegaCam) of the Virgo Cluster. One of the (many) science drivers for the NGVS is to quantify the population of intracluster globular clusters (IGCs) present between the galaxies. The large color baseline of the NGVS ugriz images allows for the effective extraction of candidates IGCs from background galaxies and foreground Milky Way stars. Here we present preliminary results on the definition of the selection of IGCs in color-color space, as well as early results on the surface density of IGCs over a large part the Virgo Cluster.

Discovery of a Large-Scale Structure of Globular Clusters in the Virgo Cluster

Myung Gyoon Lee¹, H. Park², H. Hwang³, S. Lim¹

¹Seoul National Univ., Korea, Republic of, ²Korea Astronomy and Space Science Institute, Korea, Republic of, ³CEA, France.

Exhibit Hall

Globular clusters are usually found in galaxies. Decades ago it was suggested that a cluster-wide population of globular clusters may exist in galaxy clusters. Recently we discovered a new type of large-scale structure in the Virgo cluster of galaxies: it is composed of globular clusters. Globular clusters are found wandering between galaxies (intracluster globular clusters) as well as in galaxies. These globular clusters fill a significant fraction in the area of the Virgo cluster. The distribution of the globular clusters is in general similar to that of the X-ray emitting hot gas, but shows some differences as well. The intracluser globular clusters might have been mostly stripped off from low-mass dwarf galaxies. The nature of the intracluster globular clusters is not yet known. These intracluster globular clusters will be an excellent tool to study various topics on galaxy clusters: the distribution of dark matter, the evolution of galaxy clusters, the first stellar systems in the universe, and the origin of globular clusters. Implications of our results will be discussed.

152.05

Searching for Massive Star Clusters around Luminous Blue Variables

Jared Stensland¹, M. L. Edwards², V. J. Mikles³

¹*Middlebury College,* ²*Gemini Observatory, Souther Operations Center, Chile,* ³*Department of Physics and Astronomy, Louisiana State University.*

Exhibit Hall

We present a method to search for the massive birth clusters of Luminous Blue Variables (LBVs). Using theoretical absolute magnitudes of early-type stars, we calculated expected color and magnitude limits for candidate massive stars at the distance and reddening of the Pistol Star and FMM 362 in the Quintuplet. We then applied these cuts to stars found in the 2MASS catalog surrounding the LBVs. By using a well-characterized cluster, we were able to confirm the method's effectiveness and determine the color and magnitude criteria that eliminated the highest number of false candidates while recovering the largest number of known massive cluster members. We then calculated and applied similar cuts to stars within a 1pc radius of WRA 751 to confirm its cluster, Teutsch 143a, discovered by Pasquali et al (2006) and later investigated by Froebrich et al (2008). We used our method to select 22 strong candidate massive cluster stars, 18 medium confidence candidates and 39 weak candidates, categorized based on their colors and magnitudes. These stars are prime candidates for follow-up spectroscopy to determine their spectral types and confirm cluster membership. We plan to apply a similar method to other LBVs without known birth clusters.

152.06

Using H-Alpha Morphology and Surface Brightness Fluctuations to Age-Date Star Clusters in M83 Bradley C. Whitmore¹, R. Chandar², H. Kim³, C. Kaleida³, M. Stankiewicz⁴, R. O'Connell⁵, WFC3 SOC ¹STScI, ²U. Toledo, ³ASU, ⁴JHU, ⁵U. VA.

Exhibit Hall

We use WFC3 observations of the nearby grand design spiral galaxy M83 to develop two independent methods for estimating the ages of young star clusters. The first method uses the physical extent and morphology of H-alpha emission to estimate the ages of clusters younger than ~10 Myr. It is based on the simple premise that the gas in very young (< few Myr) clusters is largely coincident with the cluster stars, is in a small, ring-like structure surrounding the stars in slightly older clusters (i.e., ~ 5 Myr), and is

in larger ring-like bubbles for older clusters (i.e., ~5 - 10 Myr). The second method is based on an observed relation between pixel-to-pixel flux variations within clusters and their ages. This method relies on the fact that the brightest individual stars in a cluster are most prominent at ages around 3 - 10 Myr, and fall below the detection limit (i.e., Mv < -3.5) for ages older than 100 Myr old. The older clusters therefore have a smoother appearance and smaller pixel-to-pixel variations. We compare age estimates of clusters in M83 derived from these two techniques with estimates determined from fitting UBVIHalpha observations with model predictions, and find good agreement at the ~90 % level, with an scatter of ~0.2 dex in log age for young clusters (< 10 Myr) and ~0.5 dex for older (> 10 Myr) clusters. This project is based on Early Release Science observations made by the WFC3 Scientific Oversight Committee. We are grateful to the Director of the Space Telescope Science Institute for awarding Director's Discretionary time for this program. Support for program #11360 was provided by NASA through a grant from the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS 5-26555.

152.07

The Star Cluster Populations in the Evolutionary Sequence of Hickson Compact Groups

Aparna Maybhate¹, K. Fedotov², I. Konstantopoulos³, J. Charlton³, A. Zabludoff⁴, R. Chandar⁵, P. Durrell⁶, S. Gallagher², P. Tzanavaris⁷

¹STScI, ²The University of Western Ontario, Canada, ³The Pennsylvania State University, ⁴University of Arizona, ⁵University of Toledo, ⁶Youngstown State University, ⁷NASA Goddard Space Flight Center. Exhibit Hall

We present a study of the three compact groups HCG 16, HCG 22, and HCG 42 observed using WFPC2 and ACS on the Hubble Space Telescope. These groups span a range of cold gas to total mass ratios defined by $log(M_{HI})/log(M_{dyn})$. Groups with lower gas content have a higher fraction of early type galaxies and thus may be more dynamically evolved. We present a comparative study of the ages and masses of star clusters in these groups based on their color-magnitude and color-color diagrams as well as their spatial distribution within the group.

152.08

Star Clusters in Intermediate-Age Galaxy Merger Remnants

Bryan W. Miller¹, G. Trancho¹, F. Schweizer²

¹Gemini Observatory, Chile, ²OCIW.

Exhibit Hall

Studies of globular cluster systems play a critical role in our understanding of galaxy formation. Star clusters are useful tracers of major star-formation events in galaxies since they are compact, relatively easy to detect, and have properties well described by simple-stellar-population models. Imaging with the Hubble Space Telescope has revealed that young compact star clusters are formed copiously during galaxy mergers, strengthening theories in which giant elliptical galaxies are formed through mergers of spirals. However, the formation and evolution of globular cluster systems is still not well understood. We should be able to observe how cluster systems evolve from the very young systems with power-law luminosity functions to old systems with log-normal luminosity functions like those observed in old elliptical galaxies. Finding intermediate-age cluster systems would constrain theories of cluster formation and destruction (evaporation, shocking, dynamical friction) as well as show the significance of merger events in the histories of galaxies. We present results of combining HST optical photometry with ground-based K-band photometry from NIRI and Flamingos-I on Gemini to study the star cluster systems of five intermediate-age merger remnants. The galaxies were chosen based on blue colors and fine structure such as shells and ripples that are indicative of past interactions. We find evidence for star clusters with ages consistent with the estimated merger ages. The properties of the star clusters systems

and implications for galaxy and star cluster formation will be discussed.

Based on observations obtained at the Gemini Observatory, which is operated by the Association of Universities for Research in Astronomy, Inc., under a cooperative agreement with the NSF on behalf of the Gemini partnership: the National Science Foundation (United States), the Particle Physics and Astronomy Research Council (United Kingdom), the National Research Council (Canada), CONICYT (Chile), the Australian Research Council (Australia), CNPq (Brazil), and CONICET (Argentina).

152.09

Observational and Numerical Constraints on Early Star Cluster Evolution

Richard de Grijs¹, R. J. Allison², Y. Hu³, L. Deng⁴, S. P. Goodwin²

¹Kavli Institute for Astronomy and Astrophysics, Peking University & The Astrophysical Journal, China, ²Department of Physics & Astronomy, The University of Sheffield, United Kingdom, ³National Astronomical Observatories & Graduate University, Chinese Academy of Sciences, China, ⁴National Astronomical Observatories, Chinese Academy of Sciences, China.

Exhibit Hall

Exciting recent developments in theory and observations call for renewed scrutiny of the early evolution of star clusters spanning a large range of parameter space. First, using a large ensemble of N-body simulations of moderately sized (N=1000), cool, fractal clusters, we find that cool, clumpy clusters dynamically mass segregate on a short timescale. This implies that the notion of 'primordial mass segregation' may be obsolete. The cluster properties also change rapidly on very short timescales: young clusters may undergo core collapse on timescales of < 1 Myr, when a dense core containing massive stars is hardened because of energy losses to a halo of lower-mass stars. In addition, we use highresolution Hubble Space Telescope imaging observations of the young (~15-25 Myr-old) star cluster NGC 1818 in the Large Magellanic Cloud to derive an estimate for the binary fraction of F stars ($1.3 < m^*/M_{\mu} <$ 1.6). Our new study provides the strongest constraints yet on the (close to) initial binary fraction in a low-metallicity environment ([Fe/H] ~ -0.4 dex). We find that our novel artificial-star-test method is sensitive to binaries with mass ratios, $q \ge 0.4$. For binaries with F-star primaries and mass ratios q > 0.4, the binary fraction is ~ 0.35. This suggests a total binary fraction for F stars of 0.55 to unity, depending on assumptions about the form of the mass-ratio distribution at low q, which is consistent with the field and lower-density clusters. This suggests that, at least among intermediate-mass stars, metallicity down to [Fe/H] ~ -0.4 dex does not suppress fragmentation and binary formation, and the binarity of these stars is at least as high as at solar metallicity. We therefore strongly argue for inclusion of realistic binary fractions in simulations aimed at following early star cluster evolution.

152.10

Tides, Rotation Or Anisotropy? Self-consistent Nonspherical Models For Globular Clusters Anna L. Varri¹, G. Bertin¹

¹Universita' degli Studi di Milano, Italy.

Exhibit Hall

Spherical models of quasi-relaxed stellar systems provide a successful zeroth-order description of globular clusters. Yet, the great progress made in recent years in the acquisition of detailed information of the structure of these stellar systems calls for a renewed effort on the side of modeling. In particular, more general analytical models would allow to address the long-standing issue of the physical origin of the deviations from spherical symmetry of the globular clusters, that now can be properly measured. In fact, it remains to be established which is the cause of the observed flattening, among external tides, internal rotation, and pressure anisotropy.

In this paper we focus on the first two physical ingredients. We start by briefly describing a recently studied family of triaxial models that incorporate in a self-consistent way the tidal effects of the host

galaxy, as a collisionless analogue of the Roche problem (Varri & Bertin ApJ 2009). We then present two new families of axisymmetric models in which the deviations from spherical symmetry are induced by the presence of internal rotation. The first one is an extension of the well-known family of King models to the case of axisymmetric equilibria flattened by solid-body rotation. The second family is characterized by differential rotation, designed to be rigid in the center and to vanish in the outer parts, where the imposed truncation in phase space becomes effective.

For possible application to globular clusters, models of interest should be those, in both families, characterized by low values of the rotation strength parameter and quasi-spherical shape. For general interest in stellar dynamics, we show that, for high values of that parameter, the differentially rotating models may exhibit unexpected morphologies, even with a toroidal core.

152.11

Photometry of the Outer Halo Globular Cluster AM 1

Brian Pohl¹, B. W. Carney¹

¹University of North Carolina, Chapel Hill.

Exhibit Hall

At a heliocentric distance of ~120 kpc, AM 1 is the most distant Milky Way

globular cluster. In an effort to further investigate this cluster, we

obtained over 17 hours of data with the SOAR telescope. We present a color

magnitude diagram, calibrated to the Johnson BV standard system, with internal errors of 0.025 mag at V = 25. The data were obtained over the course of 10 nights spanning 2007 to 2009 in the hope of detecting variable stars. We present initial results for the search for variable stars as well as revised distance, age and metallicity estimates.

152.12

HST/WFC3 Photometry of NGC 2808 and Its Multiple Main Sequences

Elizabeth Jeffery¹, T. Brown¹, A. Dotter¹, I. Hubeny², W. B. Landsman³, T. Lanz⁴, A. V. Sweigart⁵ ¹STScI, ²University of Arizona, ³Science Systems and Applications, Inc., ⁴University of Maryland, ⁵NASA Goddard Space Flight Center.

Exhibit Hall

Recent high precision photometric observations of several globular clusters have revealed that these simple stellar populations may not be as simple as we once believed. Some globular clusters have shown interesting features in their color-magnitude diagrams indicating the presence of multiple populations. Recent HST observations of the massive globular cluster NGC 2808 have revealed the presence of three main sequences. We present new observations of NGC 2808 using the new WFC3 camera on HST. Observations are in five photometric bands covering a large wavelength range from the UVIS to the IR channels of WFC3. Moreover, these observations extend below the "turn down" in the lower main sequence (as seen in the IR CMD) and therefore reach deeper than past data sets on this cluster. We discuss various model fits and compare with other observed CMDs of other globular clusters to explore the origin of these multiple sequences.

152.13

Luminosity Functions of M15

Diane Feuillet¹, B. Borland², N. Paust¹, B. Chaboyer³

¹Whitman College, ²University of Wisconsin, ³Dartmouth College.

Exhibit Hall

We present new BVI observations of the Galactic globular cluster M15 obtained with the 2.4 meter Hilter telescope at the MDM Observatory under good seeing conditions. The observations cover an area 25 arcminutes square centered on the cluster. The observations have been reduced using the DAOPHOT
stellar photometry package and extensive artificial star tests to produce detailed color-magnitude diagrams with over 50,000 stars and luminosity functions. The data extends from the tip of the red giant branch to several magnitudes below the main sequence turnoff. We compare the CMDs and luminosity functions to Dartmouth Stellar Evolution Program (DSEP) models. Using a metallicity of [Fe/H] = -2.10 we find an age of 13 Gyr and distance modulus of $(m-M)_V = 15.55$.

152.14

RGB Luminosity Functions for M2, M3, and M14

Nathaniel Paust¹, B. Chaboyer²

¹Whitman College, ²Dartmouth College.

Exhibit Hall

We present new BVI wide-field photometry of M2 (NGC 7089), M3 (NGC 5272), and M14 (NGC 6402). After extensive artificial star tests to determine completeness, this photometry is then used to create red giant branch stellar luminosity functions for the clusters. Comparisons of the observed luminosity functions to model functions from the Dartmouth Stellar Evolution Program verify that the stellar evolution models accurately predict the speed of evolution on the red giant branch. Further examination using the Kolmogorov-Smirnoff test, determines the ages and distance moduli of the clusters to be 14.0 ± 1.9 Gyr at $(m-M)_V = 15.3$ for M2, 10.3 ± 1.6 Gyr at $(m-M)_V = 15.2$ for M3, and 13.5 ± 1.6 Gyr at $(m-M)_V = 16.45$ for M14. A Monte Carlo investigation of the uncertainties involved in creating and matching theoretical luminosity functions to observations suggests a 1.2 Gyr systematic uncertainty.

152.15

Multiple Stellar Populations in Globular Clusters

Enrico Vesperini¹, S. L. W. McMillan¹, F. D'Antona², A. D'Ercole³ ¹Drexel Univ., ²INAF, Osservatorio Astronomico di Roma, Italy, ³INAF, Osservatorio Astronomico di Bologna, Italy.

Exhibit Hall

A number of spectroscopic and photometric observations have shown that many globular clusters host multiple stellar populations and challenged the common paradigm that globular clusters are 'simple stellar populations' composed of stars of uniform age and chemical composition. We present the results of a survey of simulations exploring the formation and dynamical evolution of multiple populations in globular clusters and the dependence of the amount of second-generation stars formed on a cluster's structural properties. We also present theoretical estimates of the fraction of the Galactic stellar halo composed of second-generation stars that originated in globular clusters.

152.16

Main Sequence Binary Fraction in Globular Cluster NGC 6397

Srikar Srinath¹, A. M. Cool¹, J. Anderson²

¹San Francisco State University, ²Space Telescope Science Institute. Exhibit Hall

We report preliminary results from a study of main-sequence binaries (MSBs) in the core-collapsed globular cluster NGC 6397 using the Hubble Space Telescope (HST) Advanced Camera for Surveys. We analyze images of the central regions of the cluster extending out to approximately one half-mass radius ($r_hm = 2.33$ ') taken with the Wide Field Channel in the F435W and F625W filters. After removing non-members using proper motions, we construct a color-magnitude diagram (CMD) containing 15578 cluster stars. Model cluster CMDs indicate that in the range 16 < R < 22, MSBs with mass ratio (q=M2/M1) >~ 0.6 appear sufficiently far above and redward of the main sequence ridge line to be distinguishable from the single-star sequence. Out of 10835 stars in this magnitude range, we identify an initial set of 137 stars (with primary masses in the range ~0.4-0.7 Msun) whose offset from the single-

star sequence is statistically significant. A check of quality of fit to the PSF combined with close visual inspection of the images shows that ~85 of these stars are well measured and unresolved and are thus good MSB candidates. The resulting upper limit on the fraction of MSBs with q >~ 0.6 and primaries in the range 0.4-0.7 Msun is ~0.8%. We compare our measured fraction and the radial distribution of the MSB candidates to earlier findings based on HST/WFPC2 imaging and explore the significance of the results for the total binary population in NGC 6397.

Keywords: binaries: general - globular clusters: individual(NGC 6397) - binary fraction - stars: main sequence binary

152.17

The Primordial Binary Fractions for a Sample of 35 Galactic Globular Clusters with HST Observations Jun Ji¹, J. N. Bregman¹

¹University of Michigan.

Exhibit Hall

Binaries are thought to be the primary heating energy source in globular clusters, since they can convert their binding energy to kinetic energy of the encounter stars through dynamical interactions. Even a small fraction of binaries are sufficient to prevent globular clusters from core collapse for many relaxation times. But the observed global binary fractions in globular clusters are still uncertain. Here we present our preliminary results for the binary fractions of 35 Galactic globular clusters with the HST archival data in the F606W and F814W bands. We use the secondary sequence method on the colormagnitude diagram to statistically account for the main-sequence-main-sequence binaries (primordial binaries). The binary fraction is obtained by fitting the residual color distribution after subtracting the color of the main-sequence ridge line, with properly modeling the photometric errors, field stars, and blending stars. We estimate the binary fractions with 3 different assumed binary mass-ratio distribution functions, and the current data sets are still not good to constrain the binary mass-ratio distributions. In our sample, we obtain a mean binary fraction of (9.1±4.1)% within their half-mass radii assuming a flat binary mass-ratio distribution. There is no clear trend for the binary fractions against the dynamical ages and [Fe/H], but binary fractions tend to increase with the absolute magnitudes of clusters. This is probably because less massive globular clusters consume fewer binaries through dynamical interactions due to their lower stellar density.

152.18

Variable Stars in the Globular Cluster M14

Kyle E. Conroy¹, A. N. Darragh², Z. J. Liu², B. W. Murphy²

¹Villanova University, ²Butler University.

Exhibit Hall

Using the image subtraction method of Alard & Lupton (1998) we have searched for variable stars in the globular cluster M14 (NGC 6402). Image frames were obtained during June and July 2010 using two different telescopes, the Southeastern Association for Research in Astronomy (SARA) 0.9 meter at Kitt Peak National Observatory and the SARA 0.6 meter located at Cerro Tololo Interamerican Observatory. We confirmed 62 previously known variables catalogued by Wehlau & Froelich (1994). In addition to the previously known variables, we have identified 71 new variables. We have confirmed the periods of most of Wehlau & Froelich's variables we identified with just a few exceptions. Of the total number of confirmed variables, we found a total of 112 RR Lyrae stars, several of which exhibited the Blazhko Effect. Of the total we classified 55 RR0, 57 RR1, 19 variables with periods greater than 2 days, a W UMa contact binary, and an SX Phe star. We present the periods of previously found variables as well as the periods, classification, and light curves of the newly discovered variables. This project was funded in part

by the National Science Foundation Research Experiences for Undergraduates (REU) program through grant NSF AST-1004872 and by a grant from the Butler Institute for Research and Scholarship.

152.19

Interpreting Properties of Partially Resolved Stellar Clusters

Lori Beerman¹, L. C. Johnson¹, J. J. Dalcanton¹, B. F. Williams¹

¹University of Washington.

Exhibit Hall

Any study of stellar clusters invariably involves deriving the clusters' masses, ages, and metallicities. To determine these parameters, the light from stellar clusters has traditionally been studied in one of two regimes: as a ensemble of individual resolved stars, or as a single integrated value when stars cannot be individually resolved. When studying clusters residing within nearby galaxies with the Hubble Space Telescope, both resolved and unresolved components of the light must be considered. We simulate star clusters with a range of ages, masses, and metallicities, assuming various limiting magnitudes for resolving stars, to investigate properties of the resolved and unresolved flux components. In general, most of the light is resolved in younger clusters, while most is unresolved for older clusters, suggesting that multiple detection and measurement techniques are necessary when analyzing a sample spanning a wide range of cluster ages. We also confirm that significant variations in flux and color due to stochastic effects exist for clusters whose mass is less than 10⁴ solar masses. However, we find that these effects are minimized when the brightest stars in a cluster can be resolved, and the light of the fainter, unresolved stars can be analyzed separately. These simulations can be used to shape survey design and analysis procedures in projects such as the ongoing Panchromatic Hubble Andromeda Treasury.

152.20

Deep HST Imaging in 47 Tuc and NGC 6397: The White Dwarf Cooling Sequence of 47 Tuc

Harvey B. Richer¹, J. Anderson², A. Dotter², G. Fahlman³, R. Goldsbury¹, B. Hansen⁴, J. Hurley⁵, J. Kalirai², I. King⁶, D. Reitzel⁴, R. Rich⁴, M. Shara⁷, P. Stetson³, K. Woodley¹, D. Zurek⁷

¹Univ. of British Columbia, Canada, ²STScI, ³HIA, Canada, ⁴UCLA, ⁵Swinburne University, Australia, ⁶University of Washington, ⁷AMNH.

Exhibit Hall

In Cycle 17 we were awarded 121 orbits with HST to search for the faintest stellar populations (the coolest white dwarfs, the lowest mass main sequence stars and possibly the brown dwarfs) in 47 Tucanae. It took 10 months to secure all the data with exquisite care taken to minimize the effects of charge transfer and saturation spikes. The ACS stared at a single field for all 121 orbits but the roll angle of the telescope was varied through 180 degrees for the associated parallel fields observed with WFC3. Archival data were employed to proper motion clean the images allowing virtually complete separation of field stars and those in the background Small Magellanic Cloud from those in the cluster. In this poster, we present the resultant color-magnitude diagram for this important cluster which is a proxy for the Galactic bulge. A rich white dwarf cooling sequence is revealed which will be used to determine a cooling age for the cluster for comparison with the turnoff age (see associated poster by A. Dotter et al.). Multicolor data in other ACS filters as well as four filters with WFC3 are used to examine the spectral energy distributions of the cluster white dwarfs.

Deep HST Imaging in 47 Tuc and NGC 6397: WFC3 Panchromatic Imaging of 47 Tuc

Jason S. Kalirai¹, J. Anderson¹, A. Dotter¹, G. Fahlman², B. Hansen³, J. Hurley⁴, I. King⁵, D. Reitzel³, R. M. Rich³, H. Richer⁶, M. Shara⁷, P. Stetson², K. Woodley⁶, D. Zurek⁷

¹Space Telescope Science Institute, ²HIA/NRC, Canada, ³UCLA, ⁴University of Swinburne, Australia, ⁵University of Washington, ⁶UBC, Canada, ⁷AMNH.

Exhibit Hall

In Cycle 17 our team was allocated 121 HST orbits to dissect the best studied globular cluster in the sky, 47 Tucanae. The HST ACS and WFC3 observations in this study represent one of the deepest images ever obtained for a nearby stellar population. In this poster, we present high-resolution UV and near-infrared imaging of the complete stellar populations of 47 Tuc over a wide field of view spanning a 180 degree azimuthal range and >10 pc radial range in the star cluster. The combined WFC3/UVIS and IR observations in each of these fields extends from well below the hydrogen burning limit in the red, up through the main sequence to the brightest giants in post main-sequence evolution in the visible, and down to the white dwarf cooling sequence in the blue. This complete stellar picture of a globular cluster has revealed several new features of the color-magnitude diagram and represents a comprehensive data base to test stellar evolution models in exquisite detail. In addition to the primary focus of studying 47 Tuc, our imaging penetrates through the star cluster to reveal a rich population of background giants and low mass dwarfs belonging to the distant Small Magellanic Cloud.

152.22

Deep HST Imaging in 47 Tuc and NGC 6397: Main Sequence Turnoff Ages

Aaron L. Dotter¹, J. Anderson¹, G. Fahlman², B. Hansen³, J. Hurley⁴, J. Kalirai¹, I. King⁵, D. Reitzel³, R. M. Rich³, H. Richer⁶, M. Shara⁷, P. Stetson², K. Woodley⁶, D. Zurek⁷

¹Space Telescope Science Institute, ²HIA, Canada, ³UCLA, ⁴Swinburne University, Australia, ⁵University of Washington, ⁶UBC, Canada, ⁷AMNH.

Exhibit Hall

The ages of Galactic globular clusters provide insight into the formation history of the Milky Way. Utilizing HST photometry of unprecendented depth and wavelength coverage, we determine the main sequence turnoff ages of the nearby globular clusters NGC 6397 and 47 Tuc. The ages are determined by comparing stellar evolution models to the main sequences with a chi-squared minimization technique. Our analysis of 47 Tuc leverages the pronounced 'kink' or 'knee' feature that appears in the lower main sequence in the near-IR. We present our age estimates as probability distributions and construct confidence intervals over input parameters such as metallicity, distance, and reddening.

152.23

Deep HST Imaging in 47 Tuc and NGC 6397: Variable Stars in 47 Tuc

Kristin Woodley¹, J. Anderson², S. Bickerton³, A. Dotter², G. Fahlman⁴, B. Hansen⁵, J. Hurley⁶, J. Kalirai², I. King⁷, R. M. Rich⁵, H. Richer¹, M. M. Shara⁸, P. Stetson⁴, D. Zurek⁸

¹University of British Columbia, Canada, ²STScI, ³Princeton University, ⁴HIA/NRC, Canada, ⁵UCLA, ⁶Swinburne University of Technology, Australia, ⁷University of Washington, ⁸American Museum of Natural History.

Exhibit Hall

We have obtained 121 orbits of Hubble Space Telescope imaging observations of the Milky Way globular cluster, 47 Tucanae, from which we can search for stellar variability and transits. Our differential time series photometry covers two fields located outside the cluster core. The first field was observed with the Advanced Camera for Surveys in F606W and F814W covering a 10 month time period and yielding a sample of 20 000 stars. The second field was observed with the Wide Field Camera 3 in F110W and

F160W covering 15 days and yielding an approximate sample of 10 000 stars. In this poster, we present the results of our various evaluation methods including phase dispersion minimization and a modified Lomb-Scargle periodogram to identify candidate variables and to determine their periods.

152.24

Deep HST Imaging In 47 Tuc And NGC 6397: Helium-core White Dwarfs In The Core Of NGC 6397 Ryan Goldsbury¹, K. Woodley¹, J. Anderson², A. Dotter², G. Fahlman³, B. Hansen⁴, J. Hurley⁵, J. Kalirai², I. King⁶, R. M. Rich⁴, H. Richer¹, M. Shara⁷, P. Stetson³, D. Zurek⁷

¹UBC, Canada, ²STScI, ³HIA/NRC, Canada, ⁴UCLA, ⁵U. Swinburne, Australia, ⁶U. Washington, ⁷AMNH. Exhibit Hall

We present a detailed analysis of a population of helium-core white dwarfs in the core of the Galactic globular cluster NGC 6397. We analyze the radial distribution of these objects compared to the distributions of various other populations of known mass within the this cluster. From this comparison we are able to determine the average mass of the helium-core white dwarfs and their possible binary companions. We find that their distribution is inconsistent with the expected mass range of low-mass white dwarfs, but may be explained by the presence of massive companions to these objects. We also analyze the spectral energy distributions of the He-core white dwarfs to place constraints on the nature of their unresolved partners.

152.25

Deep HST Imaging in 47 Tuc and NGC 6397: Discovery of Dwarf Novae from the Cluster Core Data David Zurek¹, J. Anderson², A. Dotter², G. Fahlman³, B. Hansen⁴, J. Hurley⁵, J. Kalirai², I. King⁶, R. M. Rich⁴, H. Richer⁷, M. M. Shara¹, P. Stetson³, K. Woodley⁷

¹American Museum of Natural History, ²Space Telescope Science Institute, ³HIA/NRC, Canada, ⁴University of California at Los Angeles, ⁵Swinburne University of Technology, Australia, ⁶University of Washington, ⁷University of British Columbia, Canada.

Exhibit Hall

We have looked for dwarf novae eruptions in the cluster cores of both 47 Tuc and NGC 6397. The cluster cores were imaged in parallel when the deep white dwarf field was imaged. We have also included archival images of the cluster cores taken with WFPC2, ACS and WFC3. We describe here all the data, our methodology and the total number of dwarf novae discovered. We explore what the number of dwarf novae implies about the total population in the cluster core.

152.26

Deep HST Imaging In 47 Tuc And NGC 6397: Stellar Dynamics On The Outskirts Of NGC 6397 Jeremy S. Heyl¹, J. Anderson², A. Dotter², G. Fahlman³, B. Hansen⁴, J. Hurley⁵, J. Kalirai², I. King⁶, R. M. Rich⁴, H. Richer¹, M. Shara⁷, P. Stetson³, K. Woodley¹, D. Zurek⁷

¹UBC, Canada, ²STSci, ³HIA/NRC, Canada, ⁴UCLA, ⁵U. Swinburne, Australia, ⁶U. Wash., ⁷AMNH. Exhibit Hall

Multi-epoch observations with ACS on HST provide a unique and comprehensive probe of stellar dynamics within NGC 6397. We are able to confront analytic, Monte Carlo and nbody models of the globular cluster with the observed stellar proper motions . The observations probe well along the main sequence from 0.5 to below 0.1 solar masses as well as white dwarfs younger than one gigayear. The observed field lies beyond the half-light radius where standard models of globular cluster dynamics (e.g. based on a lowered Maxwellian velocity distribution) make very robust predictions for the stellar proper motions as a function of mass. The observations agree with the models for the main sequence stars; however, the proper motions of the young white dwarfs are somewhat puzzling, and we examine some possible explanations.

Deep HST Imaging in 47 Tuc and NGC 6397: White Dwarfs and Brown Dwarfs in the Cluster and Field of NGC 6397

Robert Michael Rich¹, J. Anderson², A. Dotter², B. Hansen¹, H. Richer³, G. Fahlman⁴, J. Hurley⁵, J. Kalirai², I. King⁶, D. Reitzel⁷, M. Shara⁸, P. Stetson⁴

¹UCLA, ²STScI, ³UBC, Canada, ⁴HIA/NRC, Canada, ⁵Swinburne University, Australia, ⁶University of Washington, ⁷UCLA & Griffth Obs, ⁸AMNH.

Exhibit Hall

We report analysis of second epoch imaging of the very deep 126 orbit ACS integration in NGC 6397, yielding the deepest proper-motion selected color-magnitude diagram of a globular cluster. We reach past the faint end of the white dwarf cooling sequence and confirm the "blue hook" caused by H2 collision-induced absorption opacity. We also confirm a suspected population of faint red proper-motion members of NGC6397, many of which lie both fainter and redder than the theoretical limit for the hydrogen burning. Other proper motion members of NGC 6397 (with unusual colors) may be white dwarf/red dwarf binaries. Our reduced proper motion plot for the field reveals (for the first time) an extended white dwarf cooling sequence in the thick disk population, along with a well populated sequence of extremely faint red stars, many of which are also fainter and redder than the theoretical hydrogen burning limit. Supported by AURA STScI GO-11633 (R. M. Rich, PI)

152.28

Was the Progenitor of the Sagittarius Stream a Disc Galaxy? Recent Results & Observations.

Elaina A. Hyde¹, D. B. Zucker¹, J. Penarrubia², M. Irwin², R. Lane³, G. F. Lewis³, G. Gilmore², A. Koch⁴ ¹Macquarie University, Australia, ²Institute of Astronomy, University of Cambridge, United Kingdom, ³The University of Sydney, Australia, ⁴University of Leicester, United Kingdom. Exhibit Hall

Wrapping around the Milky Way, the Sagittarius (Sgr) stream is one of the most dramatic examples of a stellar tidal stream currently known. Its progenitor, the Sgr dwarf galaxy, has been assumed to be a non-rotating, pressure-supported dwarf spheroidal galaxy. However, to date, *no* such model for the interaction of Sgr with the Milky Way has been able to reproduce all of the observational features of the stream. Recent theoretical models proposing that the progenitor was a rotating *disc* galaxy may provide a solution; in particular, the bifurcation of the leading tail of the Sgr stream detected in the SDSS survey naturally arises in models where the Sgr disc is misaligned with respect to the orbital plane. If Sgr was in fact a disc galaxy, these models predict that the core should still show residual internal rotation with a measurable amplitude (~ 20 km/s). We have obtained spectra of over 2000 stars near the core of Sgr with AAOmega on the AAT in order to test the disc-galaxy hypothesis, and we present here our preliminary results, along with a comparison to model predictions.

152.29

The Nearest Old Cluster: Ruprecht 147

Jason L. Curtis¹, J. T. Wright¹

¹The Pennsylvania State University.

Exhibit Hall

Ruprecht 147 is a hitherto unappreciated open cluster that holds great promise as a standard in fundamental stellar astrophysics. At 200 pc and an age of 2 Gyr, it is the closest old cluster by factor of more than 2 in each dimension. Two previously published member lists in the literature have either completely misidentified, or have only partially identified, the cluster's stellar population. We are amidst a multi-telescope campaign to characterize R147 and catalog its members and prove its benchmark status. We have identified over 100 members including 5 blue stragglers, obtained first epoch

astrometry, and derived four-color optical photometry of the cluster core (CFHT/MegaCam). The K and M dwarfs of Ruprecht 147 will be the only old, single, cool dwarfs with known ages bright enough to admit close spectroscopic study (so far, Ca II H&K with MMT/Hectochelle).

152.30

Ionizing Sources of Extragalactic HII Regions: Tight Clusters vs. Distributed OB Associations Jessica Marie Evans¹, Y. Chu¹

¹University of Illinois.

Exhibit Hall

Extragalactic giant HII regions (EGHRs) are sites of active, concentrated star formation, providing ideal labs to analyze starburst phenomenon. The most interesting starburst issue is whether a tight cluster forms and later becomes a globular cluster or distributed OB associations form and later disperse. The two nearest EGHRs serve as standards for each; 30 Dor in the Large Magellanic Cloud hosts a dominant cluster and NGC 604 in M33 hosts multiple OB associations. To investigate the mode of star formation in EGHRs, we have searched the Hubble Legacy Archives (HLA) and identified a sample of >50 EGHRs in galaxies closer than 15 Mpc, limiting our selection by an H-alpha luminosity threshold of 1.5 x 10⁴⁰ ergs s⁻¹. Binned images of 30 Dor and NGC 604 in continuum bands are used to simulate clusters and distributed OB associations at distances of the EGHRs in our HLA sample. We have analyzed the continuum images of the EGHRs and compared them with the simulated images of 30 Dor and NGC 604 in order to assess whether the ionizing source is dominated by a tight cluster or distributed OB associations. We have also correlated the modes of star formation in EGHRs with the types of their host galaxies and their location within them. Implications of our results on starbursts and formation of EGHRs will be discussed.

152.31

X-Ray Sources in the Rich Open Cluster NGC 6819

Natalie M. Gosnell¹, D. Pooley², J. S. Kalirai³, A. M. Geller⁴, R. D. Mathieu¹, P. Frinchaboy⁵, E. Ramirez-Ruiz⁶

¹University of Wisconsin-Madison, ²Eureka Scientific Inc., ³Space Telescope Science Institute, ⁴Northwestern University, ⁵Texas Christian University, ⁶University of California. Exhibit Hall

We present the first study of the X-ray population of the intermediate-age rich open cluster NGC 6819 using the XMM-Newton Observatory. In the past decade, Chandra X-ray observations have shown a relationship between the X-ray population of globular clusters and their internal dynamics and encounter frequency. We investigate whether a similar link exists in open clusters, utilizing X-ray and UV data from XMM-Newton observations of eight rich open clusters, along with the wealth of photometry and radial velocity data from the WIYN Open Cluster Study (WOCS) and the CFHT Open Cluster Study. These results on NGC 6819 are the first of our investigation. Within the cluster apparent diameter, we detect 11 sources in NGC 6819 down to a luminosity of 10^{30} ergs/s for cluster members. Sources are classified by taking into account their broadband X-ray/UV/optical spectral properties. We gratefully acknowledge support from XMM grant NNX08AY27G from the National Aeronautics and Space Administration.

A Closer Look at Cyg OB2 using the HST Fine Guidance Sensors

Saida M. Caballero-Nieves¹, D. R. Gies¹, E. P. Nelan²

¹Georgia State University, ²Space Telescope Science Institute.

Exhibit Hall

We present results of a survey of 58 young OB stars in Cygnus OB2 that we made with the Fine Guidance Sensor 1r (FGS1r) on the Hubble Space Telescope. FGS1r in its high angular resolution TRANS mode is ideal for detecting binaries with angular separations as small as 0.012" with modest magnitude differences. We found that 22.4% of our sample are members of multiple systems (one triple detected). Using adaptive optics imaging in the infrared, we confirm 11 of the 13 multiple systems.

152.33

Measuring Spectra of B-type Stars to Study Young Open Clusters

Charisee Chiw¹, M. V. McSwain²

¹*Gettysburg College,* ²*Lehigh University.*

Exhibit Hall

We used spectra of the open clusters NGC 1960, NGC 1502, NGC 7160, NGC 2384, NGC 2244, NGC 2422, and IC 1590 to analyze their B-type stellar populations. The spectral lines He I $\lambda\lambda$ 4388, 4713, 4471, and H γ at 4340 Å were analyzed to measure the stars' projected rotational velocity, temperature, and surface gravity. Then by comparing our measurements to the evolutionary tracks of Schaller et al., we determined the masses of the stars. We determined the ages of the clusters by comparing the luminosity and temperature measurements to isochrones by Lejeune & Schaerer. Finally, we calculate the interstellar reddening and distance to each cluster. This work is supported by the NSF REU site grant PHY-0849416, NASA DPR No. NNX09AP86G, and Lehigh University.

152.34

Two Detached Eclipsing Binaries near the Turnoff of the Open Cluster NGC 6819

Mark Jeffries¹, E. L. Sandquist¹, R. D. Mathieu², A. M. Geller², J. A. Orosz¹, M. D. Shetrone³ ¹San Diego State University, ²University of Wisconsin, ³McDonald Observatory. Exhibit Hall

We analyze extensive BVR_{cl c} photometry and radial velocity measurements for Auner 259 and 537, two detached eclipsing binaries (DEBs) that are double-lined members of the moderately old (~2.5 Gyr) cluster NGC 6819. We present results of binary star modeling to measure characteristics of the components, focusing on stellar masses and radii because the binaries reside near the cluster turnoff in a color-magnitude diagram. The masses and radii will provide constraints on the cluster age. We gratefully acknowledge funding from the National Science Foundation under grant AST-0908536 and AST-0908082.

152.35

Testing Star Cluster Disruption Scenarios: Accurate Age Distributions

Allison M. Widhalm¹, G. Trancho¹, N. Bastian²

¹Gemini South Observatory, ²IoA/ Cambridge, United Kingdom.

Exhibit Hall

Due to their intrinsic brightness, star cluster populations hold the potential to accurately probe the SFH of galaxies out to distances of 10 - 100 Mpc. Their diagnostic quality, however, is limited by a poor understanding of the process of cluster disruption. Specifically, two competing empirical scenarios have been proposed, one that proposes a disruption timescale that is dependent on the cluster's mass (eg., Lamers et al. 2005), and the other which finds no such correlation (e.g., Fall et al. 2005). As Larsen (2009) has recently noted, the two scenarios predict different age-luminosity relationships, and

consequently determining the correct scenario is of utmost importance. Here we present preliminary results of the 20 brightest clusters of 3 spiral galaxies to help distinguish between these scenarios.

152.36

An Age-Sensitive Binary Star Near the Turnoff of the Open Cluster M11

Ernest Bavarsad¹, E. L. Sandquist¹, J. A. Orosz¹, M. D. Shetrone²

¹San Diego State University, ²McDonald Observatory.

Exhibit Hall

We present extensive BVR_c photometry and radial velocities for the detached eclipsing binary KV29 in the intermediate-age open cluster M11. Spectroscopy shows that the system is double-lined and is a member of the cluster. We will present the results of binary star modeling to measure the characteristics of the components. In particular, we focus in particular on the masses and radii of the components because the binary resides near the cluster turnoff in a color-magnitude diagram, and the size evolution of the brighter component leads to a strong constraint on the cluster age. We gratefully acknowledge funding from the National Science Foundation under grant AST-0908536.

we grateruny acknowledge funding from the National Science Foundation under grant A

152.37

Detailed Chemical Abundances of NGC 5128 Globular Clusters using High Resolution Spectroscopy Maria Duran¹, R. Bernstein¹

¹University of California Santa Cruz.

Exhibit Hall

Our current understanding of chemical evolution, nucleosynthesis and galaxy assembly is based largely on stellar abundance studies of old stars in only one galaxy: the Milky Way (MW). Unfortunately, beyond the MW and it's nearest neighbors, old (red giant branch) stars are too faint to observe at the high spectral resolutions(>= 20,000) and high signal-to-noise ratios (SNR >= 60)required for the analysis of individual absorption lines. While young stars can be studied at larger distances, they only record the recent gas-phase abundances. To enable chemical abundance studies of old stars at larger distances, we have developed a method to analyze high resolution (R \sim 20,000) integrated light (IL) spectra of extragalactic Globular Clusters (GCs).

GCs are unique tracers of the formation histories of galaxies; they form throughout the lifetimes of galaxies in episodes of rapid star formation (SF) and their properties are known to correlate strongly with the properties of the host galaxy (see Brodie & Strader 2006). We have demonstrated that our GC analysis provides abundances that are as accurate as standard abundance analysis of individual RBG stars, as well as accurate ages for clusters between 0.1 and 13 Gyrs. Here, we present the first detailed chemical abundances (alpha, Fe-peak, and neutron capture elements) and ages for a sample of 5 GCs in NGC 5128, the nearest E/S0 galaxy.

152.38

WIYN Open Cluster Study: Spectroscopic Abundances of M34 from the Oxygen Triplet Region Scott Adams¹, R. M. Maderak², C. P. Deliyannis²

¹University of Arizona, ²Indiana University.

Exhibit Hall

Oxygen has been suggested as a superior chronometer to iron for studying Galactic chemical evolution. Open clusters are an ideal tool for studying abundance-age relationships, given their knowable age and uniform chemical composition. As part of a larger study to investigate the O-age relationship found by King (1993) we obtained high-resolution spectra of the oxygen triplet region for 49 candidate dwarf members in M34, age 225 Myr, using the HYDRA multi-object spectrometer on the WIYN 3.5m. The following results are based on the 38 of these 49 candidate members that turned out to be slowlyrotating single-star radial velocity members. We report weighted cluster average abundances of [Fe/H] = 0.16 ± 0.03 , $[O/H] = 0.06 \pm 0.06$, $[AI/H] = -0.02 \pm 0.02$, $[Ni/H] = 0.36 \pm 0.02$, and $[Si/H] = -0.01 \pm 0.01$. Each error includes two components added in quadrature: one component is simply the standard deviation of the mean of all the cluster lines included in the average, and the other component is related to the standard deviation of the mean in the Teff, for each star, that arises from the use of multiple color indices for the derivation of Teff. Our low [O/Fe] is inconsistent with the supersolar [O/Fe] suggested by King for young clusters.

152.39

Open Cluster Neutron Capture Element Abundances and the Chemical Evolution of the Milky Way Disk Heather R. Jacobson¹, E. D. Friel², C. A. Pilachowski³

¹Michigan State Univ., ²Boston University, ³Indiana University. Exhibit Hall

Open clusters are versatile probes of the chemical abundance distribution of the Milky Way disk. Recent years have seen a steady increase in the number of open clusters subject to high resolution spectroscopic study, including the development of large samples of (10-20) clusters analyzed homogeneously. While abundances of Fe-peak, light and alpha elements in open clusters have been studied in great detail, cluster neutron capture element abundance information is relatively sparse and largely inhomogeneous, save for the barium study of D'Orazi et al. (2009). Neutron capture elements are formed in Type II supernovae and in late stages of evolution in low mass stars, and therefore yield important clues to the chemical enrichment history of the galaxy. We have undertaken a study of Ba, La and Eu abundances in some two dozen open clusters based on KPNO 4m echelle spectra and archival high resolution spectra from Keck and VLT. Our sample has a comparable range in age to the D'Orazi et al. (2009) sample and covers Galactocentric distance R_{gc}~7 - 22 kpc. Analyses of the first 11 clusters, using a spectrum synthesis technique, confirm the surprising inverse correlation between the abundance of Ba and cluster age in giants first noted by D'Orazi et al. (2009), but full confirmation awaits a larger cluster sample. We also search for similar trends in La and Eu abundances. Here we present the preliminary results of this ongoing analysis. We also search for abundance trends with cluster location in the Galaxy and compare cluster abundance patterns to those of other disk populations, which will yield clues to the formation and evolution of the Milky Way disk. This research is supported by a National Science Foundation Astronomy and Astrophysics Postdoctoral Fellowship to HRJ under award AST-0901919.

152.40

Astrometry with the Hubble Space Telescope: Improved Trigonometric Parallaxes of Selected Hyads **G. Fritz Benedict**¹, B. E. McArthur¹, W. F. van Altena², T. E. Harrison³

¹Univ. of Texas, Austin, ²Yale University, ³New Mexico State University. Exhibit Hall

We present absolute parallaxes and proper motions for seven members of the Hyades open cluster, preselected to lie in the core of the cluster. We obtain Hyad parallaxes with archival astrometric data from Fine Guidance Sensor (FGS) 3, combined with newer data for 3 Hyads from FGS 1R, both white-light interferometers on the Hubble Space Telescope. Proper motions, spectral classifications and VJHK photometry of the stars comprising the astrometric reference frames provide spectrophotometric estimates of reference star absolute parallaxes. Introducing these into our model as observations with error, we determine absolute parallaxes for each Hyad. Compared to our original (van Altena et al. 1997) determinations, our combination of new data and improved analysis lowered the individual parallax errors by an average factor of 2.9. Comparing with the four stars contained in the Hipparcos catalog, we obtain an average factor of seven improvement. Our parallax values now more closely agree with Hipparcos for the four stars in common. Additionally, we measure a perturbation orbit for vA 627, previously identified as a spectroscopic binary. Incorporating a perturbation in the modeling improves the parallax accuracy for this Hyad.

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153 *Stellar Evolution, Stellar Populations* Poster Session *Exhibit Hall*

153.01

The Quest For The Sun's Siblings: An Exploratory Search In The Hipparcos Catalogue

Jennifer Bean¹, A. Brown², S. Portegies Zwart²

¹*Missouri State University,* ²*Leiden University, Netherlands. Exhibit Hall*

We describe the results of a search for the remnants of the Sun's birth cluster among stars in the Hipparcos Catalogue. This search is based on the predicted phase-space distribution of the Sun's siblings from simple simulations of the orbits of the cluster stars in a smooth Galactic potential. For stars within 100 pc, the simulations show that it is interesting to examine those that have small space motions relative to the Sun. From amongst the candidate siblings thus selected, there are six stars with ages consistent with that of the Sun. Considering their radial velocities and abundances only one potential candidate, HIP21158, remains, but essentially the result of the search is negative. This is consistent with predictions by Portegies Zwart on the number of siblings near the Sun. We discuss the steps that should be taken in anticipation of the data from the Gaia mission in order to conduct fruitful searches for the Sun's siblings in the future.

153.02

Expanding our Knowledge of the Chemical Composition of Nearby Stars

Michael D. Pagano¹, P. Young¹, P. Butler²

¹*Arizona State University,* ²*Carnegie Institute of Washington.*

Exhibit Hall

I will be presenting abundances of X elements and physical properties for a selection of nearby radial velocity planet search candidates. The abundances are derived from high resolution spectra from MIKE on Magellan. These are the first results of an attempt to create a uniform high resolution chemical abundance database that can be used to understand the chemical evolution of nearby stars, in particular those with potentially habitable worlds. These high resolution spectra are the first from a group of 600 nearby stars, obtained by Paul Butler(Carnigie Institute of Washington).

153.03

A New Digital S Star Atlas and Its Uses

Elizabeth Otto¹, P. Green², D. Mink²

¹The Ohio State University, ²Harvard-Smithsonian Center for Astrophysics.

Exhibit Hall

S and carbon (C) stars are traditionally thought to be on the asymptotic giant branch because of their high C/O ratios and enhanced s-process elements. A sample of S stars at high Galactic latitudes would help us understand their formation and evolution in disk to halo populations, at a variety of metallicities and with minimal reddening. Faint S stars would either be at large Galactocentric radii, or dwarfs. S dwarfs are in analogy to dwarf C stars, which are thought to originate from mass transfer in a binary system. Dwarf C stars are now known to be the numerically dominant type of C star in the Galaxy, but

no S dwarfs have ever been found. Their discovery and knowledge of their space density could closely constrain some of the many available channels of binary evolution. The Sloan Digital Sky Survey (SDSS) seems an ideal place to find faint S stars, but the colors of these stars are largely unknown, since all known S stars (median V magnitude of ~10.5) are saturated in the SDSS. We use the FAST spectrograph on the Tillinghast reflector on Mt. Hopkins to obtain the spectra of 57 known S stars that appear in the Two-Micron All Sky Survey (2MASS). We flux calibrate these spectra, provide them electronically as a digital atlas, and convolve them with SDSS bandpasses to generate likely colors for S giants and dwarfs. We find that these S star colors are not clearly distinguished from the colors of M giants and C stars. We also present initial results of a cross-correlation with the SDSS spectral database, using the FAST spectra as templates. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 0754568 and by the Smithsonian Institution.

153.04

Finding the Odd One Out in Large Spectroscopic Surveys

Andrew J. Connolly¹, S. Daniel¹, L. Xiong², J. VanderPlas¹, J. Schneider² ¹Univ. of Washington, ²Carnegie Mellon University. Exhibit Hall

Through shear volume of data, next generation surveys will provide us with unprecedented and detailed information about the full distribution of astronomical sources. Anomalous events influenced by the the most extreme and interesting physics will no longer be relegated to the dustbin of "small number statistics." Unfortunately, that same volume of data will render the task of culling these extreme events from the background of ordinary stars and galaxies virtually impossible. Both the number of events and the dimensionality of the data (e.g. a spectral energy distribution measured in 4000 wavelength bins) exist well outside the reasonable limits of human processing In this context, we seek algorithms to project N>>1 dimensional data down to 2 or 3 effective dimensions, preserving the physics of the correlations within the unprojected data. Inspection in these effective dimensions then allows us to identify both objects that resemble one another (classification of objects) and objects that resemble nothing at all (anomaly detection). We consider both Principal Component Analysis, which attempts the projection under the assumption that any given data point can be reconstructed from a linear combination of all other data points, and Local Linear Embedding, which attempts to reconstruct data points only from their nearest neighbors, preserving the non-linear relationships between different neighborhoods. We use stellar spectra from the SDSS to show how these techniques can identify interesting classes of astronomical sources. We acknowledge support from the DOE Applied Mathematics Program DE-FG02-87ER40315

153.05

Stellar Rotation and Activity at 1 Gyr: The Palomar Transient Factory Does NGC 752

Marcel A. Agueros¹, P. A. Cargile², K. R. Covey³, A. L. Kraus⁴, N. M. Law⁵, K. G. Stassun² ¹Columbia Univ., ²Vanderbilt Univ., ³Cornell Univ., ⁴Univ. of Hawaii, ⁵Univ. of Toronto, Canada. Exhibit Hall

Large uncertainties remain in our picture of the evolution of stellar rotation and activity in Sun-like stars after they reach the age of the Hyades, roughly 0.5 Gyr. Rotation periods are scarce for stars at these ages, seriously complicating the calibration of an age-rotation-activity relation that could be applied to field stars. The Columbia/Cornell/Caltech Palomar Transient Factory (CCCP) survey of open clusters is an effort to systematically map stellar rotation in nearby open clusters. We present preliminary results from our on-going CCCP campaign on NGC 752, a ~1 Gyr open cluster for which we have several hundred individual R-band observations. At a distance of only ~450 parsecs, and with deep archival X-ray

observations, it represents the best opportunity we have to study the age-rotation-activity relation in main sequence stars at an age about a quarter that of the Sun.

153.06

The Columbia/Cornell/Caltech Palomar Transient Factory (CCCP) Praesepe Campaign: Studying the Rotation-Activity Relation in an Intermediate Age Cluster

Kevin R. Covey¹, J. Lemonias², M. Agueros², N. Law³, A. Kraus⁴, K. Hamren¹

¹Cornell University, ²Columbia University, ³University of Toronto, ⁴University of Hawaii, Monoa. Exhibit Hall

For several decades, observational surveys have demonstrated a closerelationship between a star's rotation period, magnetic activity, and age. The age-activity-rotation relation is well documented in clusters younger than 500 Myrs, but its subsequent evolution is less clear. Using wide-field, multi-epoch photometry from the Palomar Transient Factory, we have monitored ~530 members of the Praesepe open cluster, a ~600 Myr nearby Hyades analog. With light curves containing >150 measurements over more than three months, we have measured rotation periods for ~50 K & M-type cluster members. These rotation periods span the gap between the periods measured for solar-type Hyads and the lowest-mass Praesepe members, and indicate that the orderly mass-rotation relation seen for higher mass Praesepe members begins to break down at ~0.6 M_{sun} . Below this critical mass, a range of rotation periods spanning an order of magnitude are observed for stars with similar masses. Combining these rotation measurements with archival X-ray and Halpha observations completes the portrait of the ~600 Myr age-activity-rotation relation, and enables a detailed comparison with Praesepe's sister cluster, the Hyades.

153.07

TripleSpec Observations of Candidate PTF Eclipsing Binaries

Katie Hamren¹, K. Covey¹, N. Law², M. Agueros³, J. Lemonias³, A. Kraus⁴

¹Cornell University, ²University of Toronto, Canada, ³Columbia University, ⁴University of Hawaii. Exhibit Hall

The Columbia-Cornell-Caltech Palomar Transient Factory (CCCP) survey is designed to obtain stellar rotations in a number of nearby open clusters. Among the interesting objects detected in CCCP fields observed to date are several candidate eclipsing binaries with M star primaries. These systems, whether in the field or in our target clusters, are ideal laboratories for testing models for the masses and temperatures of late-type stars. The challenge is in obtaining and analyzing the high quality follow-up spectroscopy that is required for these tests. Here we report on our use of the near-infrared TripleSpec spectrometer on the 200-inch telescope at Palomar Observatory to follow up on these interesting systems. While these observations are of moderate resolution (R \sim 3000), they do provide sufficient traction to constrain the radial velocity separation of the two components of the binary, allowing us to place constraints on the orbits of these systems.

153.08

Chemical Compositions of Field Red Horizontal Branch Stars

Melike Afsar¹, C. Sneden¹, B. For¹

¹*The University of Texas at Austin.*

Exhibit Hall

Field Red Horizontal Branch stars (RHBs) are alleged to be members of the thick disk of our Galaxy and are an important evolutionary link between horizontal and asymptotic giant branch evolution. They are easy to identify in globular clusters through their color-magnitude diagram positions. However, they are harder to identify as single stars in the general field; thus they have received lesser attention to date. In this study, we composed a large catalog of RHB candidates and performed the first large-sample high-

resolution spectroscopic survey of these stars. We have obtained high resolution spectra of a number of candidate field RHBs. The high resolution spectra of these stars were taken with the 2.7m Harlan J. Smith Telescope and Tull 2Dcoude (R=60000) spectrometer at McDonald Observatory. We have derived the metallicities and relative abundance ratios for some of the alpha (Ca and Si) and neutron capture (La and Eu) elements along with the fundamental stellar parameters. We have also determined CNO abundances in order to gain insight into the evolutionary states of the candidates. In particular, we have investigated the 12C/13C ratio using the CN features present in the 8000-8040 A region, which we have also used to obtain the N abundances of the candidates. Plausible RHB stars, members of the thick disk, found in our study, can shed light into Galactic evolutionary models.

This project has benefitted from the financial support of NSF (AST-0908978), the Rex G. Baker endowment to the University of Texas Astronomy Dept., and The Scientific and Technological Research Council of Turkey (TUBITAK).

153.09

Looking for Metallicity Spread in Clusters Using HST/WFC3 Multiband Photometry

Daniel Oravetz¹, J. A. Holtzman¹

¹New Mexico State University.

Exhibit Hall

We describe efforts to study the internal distribution of metallicites in stellar clusters using multiband HST/WFC3 images that include observations in filters that are designed to be more sensitive to metallicity than standard broadband filters. We analyze observations of NGC 6791, NGC 5927, NGC 104, NGC 6752, and M92, which span a range of metallicities, -2.2 < [Fe/H] < 0.35. We search for metallicity spread by comparing the observed width of the stellar locii in several different color indices to the spread expected from photometric errors.

153.10

Calibrating Measurement of Stellar Metallicities from Multiband HST/WFC3 Photometry

Jon A. Holtzman¹, B. Anthony-Twarog², H. Bond³, D. Oravetz¹, A. Saha⁴, B. Twarog², A. Walker⁵ ¹New Mexico State Univ., ²Univ. of Kansas, ³STScl, ⁴NOAO, ⁵CTIO.

Exhibit Hall

We present initial results from a HST/WFC3 calibration project to understand how well stellar metallicities can be determined from multiband photometry that includes filters specifically designed for helping to derive stellar parameters. We report on observations taken in a suite of 11 filters: F336W, F390M, F390W, F395N, F410M, F467M, F547M, F555W, F814W, F110W, and F160W. Data in these filters was obtained in five Milky Way clusters -- M92, NGC6752, NGC104, NGC5927, and NGC6791 -that span a large range in metallicity. The resulting stellar sequences are compared with model predictions, and results on the most promising metallicity indicators are discussed.

153.11

Chemical Abundances in Carbon-enriched Metal-poor Stars

Anna Kwa¹, J. Johnson¹, T. Masseron², D. Lai³, M. Bolte³, S. Lucatello⁴

¹Ohio State University, ²Université Libre de Bruxelles, Belgium, ³UCO/Lick Observatory, ⁴Osservatorio Astronomico di Padova, Italy.

Exhibit Hall

The metal-poor population II stars in the Galactic halo formed during the first few generations of star formation following the Big Bang, and can thus provide key insights into conditions in the early Universe. Carbon-enriched metal-poor (CEMP) stars, a subset of this population, are of even further interest because of their peculiar chemical abundance patterns. High-resolution spectra of ten known CEMP stars were obtained on the Keck High Resolution Echelle Spectrometer (HIRES) for this study. Stellar

parameters for our model atmospheres were determined using Fe I and Fe II equivalent width measurements. We derived chemical abundances from measured equivalent widths whenever possible, or from synthetic spectra in the cases where no equivalent widths could be measured for an element's spectral lines. Using these methods, we have obtained preliminary abundances for up to 28 elements in our sample. Further work remains in introducing carbon into the model atmospheres and repeating the abundance analysis using these revised models. We can then study the relative abundances of heavy elements in comparison to solar system r-process and s-process abundance patterns in order to infer possible mechanisms by which these stars became carbon-enriched.

153.12

The Chemical Composition of Bulge Stars in Plaut's Window

Christian I. Johnson¹, R. M. Rich¹, J. P. Fulbright², D. B. Reitzel³

¹University of California, Los Angeles, ²Johns Hopkins University, ³Griffith Observatory. Exhibit Hall

We present chemical abundances for ~100 red giant branch (RGB) and red clump stars in Plaut's lowextinction window (I,b)=(0°,-8°). The abundances were determined from equivalent width and spectrum synthesis analyses of high resolution (R=22,000), high signal-to-noise (S/N~50-100) spectra obtained with the Blanco 4m telescope and Hydra multifiber spectrograph. We confirm the existence of a vertical metallicity gradient along the Galactic bulge minor axis and that the median metallicity at b=-8° is [Fe/H]~-0.3. However, the red clump stars in this field appear to be both selectively enhanced in metallicity, with a median [Fe/H]~0, and have at least a factor of two smaller radial velocity dispersion than the RGB stars. Interestingly, both the giants and clump stars exhibit similar enhanced [alpha/Fe] ratios compared to the thin and possibly thick disk trends, and the b=-8° [alpha/Fe] ratios are indistinguishable from those at b=-4°. Lastly, we compare the abundances of several additional light and heavy elements in Plaut's Window to those in other bulge fields and stellar populations.

153.13

The Chemical Composition of Globular Cluster M68

Sloane K. Simmons¹, C. Sneden¹, G. Preston², I. Thompson², J. Sobeck³, S. Shectman² ¹University of Texas, ²Carnegie Observatories, ³University of Chicago. Exhibit Hall

We present a chemical composition study of twenty-five stars in the metal-poor Galactic globular cluser M68. We obtained high-resolution spectra (R ~ 40,000) in the wavelength region 3500-9000 A for the target stars with the the Magellan Inamori Kyocera Echelle (MIKE). The observed stars include 11 red giant branch (RGB) stars, 9 red horizontal branch (RHB) stars, and 5 blue horizontal branch (BHB) stars, which span an effective temperature range of approximately 5000K. The abundances were determined through equivalent width and synthetic spectrum analyses. The computations considered isotropic, coherent scattering in the continuum source functions. Sample stars from each group were analyzed using model atmospheres from the MARCS and ATLAS grids. We find a generally consistent metallicity across all the evolutionary groups: [Fe/H] = -2.4 (RMS deviation = 0.1). However, we note that the mean RHB metallicity is ~0.15 dex less than the overall average. The relative abundance ratios of the alpha elements are typical for low metallicity stars: [Ca/Fe] = [Ti/Fe] ~ +0.35, with only small variations among the RGB, RHB, and BHB stars. Star-to-star variations in proton-capture elements Na, O, and Al are apparent in the spectra. We will present representative abundances from other major element groups in all three stellar evolutionary domains.

Acknowledgements: we are grateful to NSF grant AST-0908978, the University of Texas John W. Cox Endowment for Advanced Studies in Astronomy, and the University of Texas Astronomy Department Rex G. Baker, Jr. Endowment for support of this project.

An Abundance Analysis of Red Giant Stars in the Retrograde Galactic Globular Cluster NGC 3201: Implications for Cluster Formation Scenarios

Jennifer A. Simmerer¹, I. I. Ivans¹

¹University of Utah.

Exhibit Hall

Globular clusters have long been central to the study of Galactic Chemical Evolution. They serve as laboratories for stellar physics, evolution, and nucleosynthesis as well as representing fossil remnants of Galactic assembly processes. Our work addresses two recent areas of interest: globular clusters as accreted objects and globular clusters as hosts for multiple stellar populations. The globular cluster NGC 3201 is a curious object on a retrograde orbit. Some studies suggest that it contains stars of more than one metallicity, a property seen only in the peculiar globular cluster Omega Centauri. Both properties hint at an extra-Galactic origin. We present an elemental abundance pattern for NGC 3201 based on high resolution, high signal-to-noise spectra of red giant stars. We present abundance patterns of similar stars from the globular cluster M5 for comparison. Interpretation of our results is complicated by the discovery that at least two of our giants are variable stars. Though we can derive adequate stellar parameter solutions for both stars in every stage of variability and heavy element abundances do not change with the stellar phase, the abundances of the light elements O, Na, Mg, and Al are extremely unstable and vary greatly. Our inability to correctly model light element line formation in the atmosphere of variable red giant stars has significant implications for studies of star to star abundance variations in exactly these elements in globular clusters, which rely on stars at the same evolutionary stage as the variables in NGC 3201.

153.15

Near Infrared Spectra of SAGE LMC AGB Stars

Robert D. Blum¹, K. Volk², S. Srinivasan³

¹NOAO, ²STScI, ³IAP, France.

Exhibit Hall

We present *K*-band spectra of a sample of *Spitzer* SAGE LMC sources obtained on the 4-m SOAR telescope in Chile. The near infrared spectral classifications are compared to classifications from *Spitzer* IRS spectra of the same sources and to the original SAGE IRAC and MIPS photometric classifications. The SOAR Telescope is a joint project of: Conselho Nacional de Pesquisas Cientficas e Tecnolgicas CNPq-Brazil, The University of North Carolina at Chapel Hill, Michigan State University, and NOAO (which is run by the Association of Universities for Research in Astronomy on behalf of the National Science Foundation).

153.16

The O I $\lambda7774$ Line as a Luminosity Indicator in M31

Joanna Taylor¹, P. Massey¹, M. Drout¹, S. Tokarz², N. Caldwell² ¹Lowell Observatory, ²Smithsonian Astrophysical Observatory. Exhibit Hall

Yellow supergiants are very useful tools in determining the accuracy of current stellar evolutionary models. These stars represent a short phase in a supergiant's life; typically they will live only thousands of years. Because of this, their positions on the H-R diagram can reveal errors in current models. Identifying stars as yellow supergiants, however, has proved difficult as foreground Milky Way dwarfs can have similar colors and magnitudes. Still, Drout et al. (2009) and Neugent et al. (2010) identified yellow supergiant members from foreground non-members by using stars' radial velocities. How does one identify yellow supergiants in galaxies without significant rotational velocity, though? In an effort to

answer this, we have turned our attention to the O I λ 7774 triplet. This line has been known to be a luminosity indicator in F-type supergiants due to Non-Local Thermal Equilibrium (LTE) and sphericity effects (Osmer 1972). We analyzed the spectra of ~900 stars in M31, obtained with the Hectospec multifiber spectrometer on the MMT. This sample included 48 rank-1 (nearly certain) M31 members (Drout et al. 2009), looking specifically at the λ 7774 line. There was found to be a limit that determines what a 'significant' amount of oxygen is, at approximately 1.2 Å. We found that the majority of previously known rank-1's had a significant amount of oxygen, while ~11% of rank-2's (probable yellow supergiants) and less than 1% of rank-3's (foreground dwarfs) had a significant amount. These results imply that the O I λ 7774 will indeed work as a luminosity indicator.

This work was supported by the National Science Foundation through grants AST-1008020 and AST-1004107.

154

Stellar Atmospheres, Winds Poster Session *Exhibit Hall*

154.01

Radio And X-ray Emission From Magnetic, Early-type Stars: A Progress Report Stephen Alan Drake 1

¹USRA/CRESST and NASA/GSFC.

Exhibit Hall

Radio emission from the classic magnetic early-type stars, the Ap/Bp stars, has been studied since 1985 and its general characteristics and nature seems fairly well understood, e.g., that they can be quite radio-bright and that the dominant emission mechanism is gyrosynchrotron emission. The X-ray emission properties of this stellar class have been harder to pin down, primarily because they are not particularly bright in X-rays, making it difficult to discriminate intrinsic from external emission, e.g., from low-mass coronal companions. With the recent discovery that weaker but still significant magnetic fields are present in many 'normal' early-type stars, it seems timely to re-explore the degree of dependence of the emission in these energy bands on their magnetic fields, as the latter vary over 2-3 orders of magnitude.

154.02

Stellar Spectral Synthesis with OpenGL

Nicholas R. Hill¹, R. Townsend¹

¹University of Wisconsin-Madison.

Exhibit Hall

Given an appropriate model atmosphere, synthesizing the spectrum of a star is a relatively straightforward task -- *if* the star is spherical and homogeneous across its surface. Many astronomically interesting objects do not, however, fall into this category. Examples include single stars that are spotted, rapidly rotating or pulsating, and binary stars in eclipsing or ellipsoidal-variable configurations. To synthesize a spectrum in such cases, it is necessary to construct a 3-D model of the stellar surface; determine which regions of the surface are visible to an external observer; and then calculate the observer-directed radiation from these regions.

The Open Graphics Library (OpenGL), a cross-platform application programming interface for creation of 2-D and 3-D graphics, already includes much of the functionality required to implement these steps. We describe a new approach to stellar spectral synthesis that leverages this functionality. A 3-D mesh is constructed to represent the (possibly non-spherical) geometry of the stellar surface (or surfaces, in the case of binary or multiple systems). Textures are laid over this mesh to represent the run of physical

attributes such as temperature, gravity, velocity, etc. The textured mesh is then rendered by OpenGL into a framebuffer, a step which naturally takes care of projection and occultation effects. The attributes of each framebuffer pixel are used to look up an appropriate spectrum in pre-calculated tables of specific intensities; and finally, summing the spectra from all pixels gives the disk-integrated synthetic flux spectrum of the star. The advantage of this approach lies in its efficiency (many OpenGL features are hardware-implemented), flexibility and manifest simplicity. Possible applications include binary light-curve modeling, mode identification in pulsating stars, and stellar population synthesis.

154.03

Abundance Results from the Las Campanas Observatory and McDonald Observatory High-Resolution Metal-Poor Star Survey

Ian U. Roederer¹, G. Preston¹, S. Shectman¹, I. Thompson¹, C. Sneden² ¹Carnegie Observatories, ²University of Texas.

Exhibit Hall

We have undertaken a survey to collect high-resolution and high S/N spectra for more than 300 metalpoor stars. The majority of our sample was selected from the HK Survey of Beers, Preston, and Shectman, and nearly all stars with estimated [Fe/H] < -2.5 have been observed with the MIKE spectrograph on the Magellan-Clay Telescope at Las Campanas Observatory. Additional metal-poor targets were selected based on their kinematic properties and observed with the Tull spectrograph on the Smith Telescope at McDonald Observatory. Previous abundance analyses based on high-resolution and high S/N spectra have been performed for only about 20% of the sample. While this sample naturally allows us to reconfirm and expand upon previously-detected low metallicity abundance trends and identify new stars with unique abundance signatures, its real power is the ability to probe chemical dispersion in abundance ratios. We exploit this attribute by performing line-by-line differential abundance analyses for many elements in large numbers of stars at a single metallicity and evolutionary state. This allows us to assess the evolution of the cosmic scatter of the chemistry of the ISM at very early times in the halo of the Galaxy. Generous funding has been provided by the U.S. National Science Foundation (grant AST 09-08978 to C.S.).

154.04

Asymptotic Giant Branch Stars in the Magellanic Clouds: Dust Production and Mass Return.

Martha L. Boyer¹, S. Srinivasan², SAGE-SMC Spitzer Legacy Team

¹STScI, ²IAP, France.

Exhibit Hall

The Small Magellanic Cloud (SMC) was imaged from 3.6 to 160 microns as part of the Legacy program entitled: "Surveying the Agents of Galaxy Evolution in the SMC", or SAGE-SMC. These wavelengths are ideal for studying circumstellar dust, and the full spatial coverage of the SMC (including the bar, wing, and tail) allows for a statistically complete study of its entire dust-producing Asymptotic Giant Branch (AGB) star population. Here, we present the infrared colors and spectral energy distributions of AGB stars, particularly with respect to dust production and mass loss. We also compare the SMC AGB population to those in the higher-metallicity LMC and other metal-poor Local Group dwarf galaxies to assess the influence of metallicity on AGB dust production.

This work is supported by Spitzer via JPL contracts 1309827 and 1340964.

AGB Stars In AKARI And IRAS Two-color Diagrams

Kristen Koopman¹, L. Sjouwerman², M. Claussen²

¹Sarah Lawrence College and National Radio Astronomy Observatory, ²National Radio Astronomy Observatory.

Exhibit Hall

Infrared measurements such as from the Infrared Astronomical Satellite (IRAS) all-sky survey and the Midcourse Space Experiment (MSX) Galactic plane survey have been used to statistically distinguish between different types of objects. In particular, two-color diagrams characterize Asymptotic Giant Branch (AGB) stars with different circumstellar shell opacity and thickness, and whether the source is oxygen- or carbon-rich in nature (Van der Veen & Habing 1988, A&A 194, 125; Sjouwerman et al. 2009, ApJ 795, 1554).

We present two-color diagrams for AGB stars using infrared data from the AKARI satellite all-sky survey (e.g. Ishihara et al. 2010, A&A 514, A1) and created categories analogous to those for IRAS and MSX twocolor diagrams. Our system specifically selects for circumstellar envelopes that are conducive in sustaining SiO maser emission. About 200 new sources were identified in the AKARI data. This research was supported by the Research Experience for Undergraduate Program of the National Science Foundation, and was completed at the National Radio Astronomy Observatory in Socorro, New Mexico.

154.06

λ Vel (K4 Ib-II): Fluorescence on a PAR with Other Luminaries

G. M. Wahlgren¹, K. G. Carpenter², T. R. Ayres³, A. Brown³, G. M. Harper⁴ ¹*CUA/NASA-GSFC*, ²*NASA-GSFC*, ³*UCO*, ⁴*TCD*, *Ireland*.

Exhibit Hall

The ultraviolet spectral region of cool, luminous stars contains emission features that originate from fluorescent mechanisms via PAR (photo-excitation by accidental resonance). These mechanisms can account for numerous emission lines, downward transitions from upper energy levels pumped by strong transitions, such as H Ly- α , O I 1302, C II 1335, and Mg II h&k. A new, high S/N observation of the cool giant star λ Vel (K4 Ib-II) was obtained with the HST/COS instrument at a resolving power of R ~ 20000 and covers the wavelength region from 132 nm to 147 nm. High-quality spectra (COS and GHRS) are now available from 128 nm to 147 nm, and at 12 moderate and high resolution observations from the HST/GHRS, the latter covering approximately a third of the wavelength interval from 189 nm to 285 nm. Using these data, together with observations from FUSE and IUE, we investigate PAR processes in the spectra of Cr II and Fe II and make comparisons with other stars. The presence of additional atomic (O I, S I, and Cl I) and molecular (H2, CO) PAR processes in the spectrum of λ Vel is briefly discussed.

154.07

The Chromospheric Structure and Wind of the K-Supergiant Lambda Velorum

Kenneth G. Carpenter¹, T. R. Ayres², A. Brown², G. M. Harper³, G. M. Wahlgren⁴

¹NASA's GSFC, ²University of Colorado, ³Trinity College Dublin, Ireland, ⁴NASA's GSFC/Catholic Univ. of America.

Exhibit Hall

Recently, the 1326-1466 Å region of the FUV spectrum of the K4 Ib-II supergiant Lambda Vel was observed with the Cosmic Origins Spectrograph (COS) on HST, as part of the Ayres and Redfield Cycle 17 SNAP program "SNAPing Coronal Iron." This spectrum covers a region not previously recorded in Lambda Vel at high resolution and, in a mere 20 minutes of exposure, reveals an amazing treasure trove of information. It shows a wide variety of strong atomic and molecular emission lines formed in the

chromosphere and multiple atomic absorption lines formed in the stellar wind, both superposed on a bright chromospheric continuum. Further evidence of the stellar wind is seen in the P Cygni profiles presented by the C II (UV 1) lines near 1335 Å. We combine this COS data with archival GHRS spectra of other selected FUV and NUV regions to better characterize the outer atmospheric structure of the star and its massive, outflowing wind.

154.08

Near-Infrared Mass Loss Diagnostics for Massive Stars

George Sonneborn¹, J. C. Bouret¹

¹NASA's GSFC.

Exhibit Hall

Stellar wind mass loss is a key process which modifies surface abundances, luminosities, and other physical properties of hot, massive stars. Furthermore, mass loss has to be understood quantitatively in order to accurately describe and predict massive star evolution. Two urgent problems have been identified that challenge our understanding of line-driven winds, the so-called weak-wind problem and wind clumping. In both cases, mass-loss rates are drastically lower than theoretically expected (up to a factor 100!). Here we study how the expected spectroscopic capabilities of the James Webb Space Telescope (JWST), especially NIRSpec, could be used to significantly improve constraints on wind density structures (clumps) and deep-seated phenomena in stellar winds of massive stars, including OB, Wolf-Rayet and LBV stars. Since the IR continuum of objects with strong winds is formed in the wind, IR lines may sample different depths inside the wind than UV-optical lines and provide new information about the shape of the velocity field and clumping properties. One of the most important applications of IR line diagnostics will be the measurement of mass-loss rates in massive stars with very weak winds by means of the H I Brackett alpha line, which has been identified as one of the most promising diagnostics for this problem.

154.09

OB-wind X-ray/Bolometric Luminosity Proportionality as a Coincidence of the Parameters Kenneth G. Gayley $^{\rm 1}$

¹Univ. of Iowa.

Exhibit Hall

X-ray luminosities of single OB and early-type WN stars show a tendency to scale with the stellar bolometric luminosity. A long-standing question is whether this is essentially a coincidence of the parameters that generate X-ray emission from the generally nonlinear wind strength, or if it is indicative of some X-ray generation process that more directly taps into the bolometric luminosity via some consistent conversion efficiency. Here I explore the former possibility by adopting a novel approach to the general scaling laws for X-ray emission from embedded wind shocks, and find that a coincidental connection between the various nonlinear scalings, resulting in a net response that is broadly proportional to stellar luminosity, is a plausible resolution of this puzzle. This work was supported by a NASA ADP grant.

154.10

Variability in OB Star X-ray Emission Lines: Analysis Techniques

Joy S. Nichols¹, A. W. Mitschang¹, W. Waldron²

¹Harvard-Smithsonian, CfA, ²Eureka Scientific, Inc..

Exhibit Hall

X-ray emission lines in the spectra of hot stars are expected to vary over short or long periods due to a number of phenomena related to the wind, a companion, or the star itself. Such variations are difficult to quantify due to the comparatively low signal-to-noise in the existing data and the lack of extensive

temporal coverage. We utilize several quantitative methods, including a Monte Carlo technique and KS tests, to evaluate emission lines in X-ray spectra for short-term variability based on time-sliced spectra. Our sample of test spectra includes several co-added spectra of multiple observations of a target, as well as four O stars that were serendipitously observed during observations of other targets. We discuss the probability of detecting short-term variations in the He-like emission lines of several hot stars in HETG Chandra data and the need for deeper exposures.

154.11

Long-term Spectroscopic Variability of Luminous Blue Variables

Noel Richardson¹, D. R. Gies¹, N. D. Morrison² ¹Georgia State University, ²University of Toledo.

Exhibit Hall

We report on the preliminary results of a three-year monitoring campaign of southern luminous blue variables with the Cassegrain and Echelle spectrographs at the CTIO 1.5 m telescope. We have collected more than 300 moderate-resolution spectra of 20 stars in the red portion of the optical spectrum, which includes the wind-sensitive transitions of H-alpha and He I 5876 and 6678 Angstroms. We present initial results on the variability of the sample. We find several stars exhibiting observational evidence of changes in the emission line morphology that reflect changes in the wind structure. We also present a detailed study of 15 years of high resolution H-alpha spectroscopy from Ritter Observatory of the prototypical luminous blue variable, P Cygni. We report on the discovery of discrete absorption components in P Cygni's H-alpha profile, and we discuss their relationship to the long-term photometric and emission line variability.

154.12

Tracking Eta Car Through the 2009 Event

John C. Martin¹, A. Mehner², K. Davidson², R. M. Humphreys², K. Ishibashi³, G. Ferland⁴ ¹U of Illinois Springfield, ²U of Minnesota, ³Nagoya University, Japan, ⁴U of Kentucky. Exhibit Hall

Eta Carinae's 2009 spectroscopic event showed significant differences with the two previous wellobserved events in 1998.0 and 2003.5. Photometry and spectra gathered with HST and Gemini/GMOS in late 2008 and early 2009 show differences with past events including: 1. a much deeper minimum brightness during the 2009 event and 2. differences in the spatially resolved spectrum during the event that may indicate a significant change in the structure and physical parameters of the wind. Taken together with other data including the early return of X-rays after the event, we believe this represents a critical data point in understanding the nature and continued evolution of Eta Carinae.

155 *The Sun* Poster Session *Exhibit Hall*

155.01 Active Region Segmentation Based on Stokes Asymmetries Jieun Choi¹, B. Harker-Lundberg² ¹UC Berkeley, ²National Solar Observatory.

Exhibit Hall

During the Stokes inversion process, we would ideally use a distinct model for each structure in an active region which addresses the differences in the physical conditions of these regions. While the Milne-Eddington model of the atmosphere---a frequently-used ideal model that assumes all local

thermodynamic equilibrium (LTE) conditions are satisfied----is a sufficient approximation for the description of the solar photosphere, we almost always observe deviations from this model. It is thus of interest to devise a method to systematically and accurately identify the active regions based on their spectra, such that we could use a more sophisticated model catered to each structure in an active region during the actual Stokes inversion process. We present a classification scheme for different active region structures using Stokes asymmetries and line core depths as discriminators. The data used for this investigation were obtained from the Synoptic Optical Long-term Investigations of the Sun (SOLIS) facility using the Vector Spectromagnetograph (VSM), observed in a 3 A bandpass around Fe I 6302.5 A, from March 27, 2008 to March 29, 2008. This work is carried out through the National Solar Observatory Research Experiences for Undergraduate (REU) site program, which is co-funded by the Department of Defense in partnership with the National Science Foundation REU Program. The National Solar Observatory is operated by the Association of Universities for Research in Astronomy, Inc. (AURA) under cooperative agreement with the National Science Foundation.

155.02

Spectroscopic Imaging of the Dynamic Quiet Sun using the Murchison Widefield Array Prototype Interferometer

Lynn D. Matthews¹, D. Oberoi¹, R. Kennedy², Murchison Widefield Array Team ¹*MIT Haystack Observatory*, ²*University of California Berkeley*.

Exhibit Hall

We will present results from recent spectroscopic imaging observations of the solar corona obtained with the Murchison Widefield Array (MWA) Prototype interferometer. The 32-element MWA Prototype operates between 80-300 MHz and is a precursor to the full 512-element MWA that is currently under construction in Western Australia. The combination of high spectral resolution and high dynamic range imaging capabilities afforded by the MWA Prototype are already providing a wealth of new insights into the dynamic nature of the radio Sun. For example, during two separate days in late March 2010 (characterized as "quiet" to "very quiet" by the NOAA Space Weather Prediction Center), we have detected modest level broad-band bursts that are similar to classic Type III bursts in their duration and peak wavelengths. On one of these days, we also detected and imaged numerous short-lived, narrowband events whose nature is clearly non-thermal, but whose properties, to our knowledge, do not match those of any other previously reported class of radio burst. All of the temporally variable features appear to be linked with x-ray-bright active regions. In some cases, we also observe circularly polarized emission at these locations. Our observations and analysis are ongoing, and we will use these and other new results to illustrate the powerful new capabilities for solar and heliospheric research that will be provided by the full MWA over the next several years. This research was supported by a grant from the National Science Foundation.

155.03

Tracked Motions of G-band Bright Points

Olivia Telford¹, S. L. Keil²

¹University of Pittsburgh, ²National Solar Observatory. Exhibit Hall

Abstract

Bright points (BPs) are magnetic elements in the photosphere observable in the CN G-band at 4305 Å. High-speed speckle images were taken with the Dunn Solar Telescope in Sunspot, NM with a 80 frame burst every ~32 seconds, achieving a resolution of 0.1422" in the reconstructed images. The BPs were tracked by hand and velocities and curls (vorticity) were derived at each time step. Small-scale motions were also tracked using a FFT local correlation tracking algorithm. The velocities obtained from correlation tracking were generally smaller by factors of 2 to 5 than the hand tracked motion in agreement with previous results, however, the hand-tracked BPs tended to move in the direction of the local correlation tracking velocities. The velocities of the BPs were used to estimate the energy associated with these motions, which was found to vary between 1 to $^3*10^{17}$ erg cm⁻¹ based on observed velocities between 2 to 7 km s⁻¹. This amount of energy could provide a source of heat for the corona, which has a minimum energy requirement of 10^6 erg cm⁻² s⁻¹. In some cases, BPs were seen to travel at 7 km s⁻¹, and changed their direction of motion after collisions with granules. These supersonic speeds could generate shockwaves, which in turn could transfer energy from the BPs to the magnetic field. BPs often spiral around each other, possibly entangling the associated magnetic field providing a mechanism by which energy could be transported to the corona.

This research was funded by the National Science Foundation as part of its REU program.

155.04

Effect of Solar Flares on Acoustic Oscillations Within the Sun

Kendra Kellogg¹, S. Tripathy¹, K. Jain¹

¹National Solar Observatory.

Exhibit Hall

We investigate the effects that energetic flares have on the acoustic oscillations observed on the surface of the sun. We use the ring-diagram technique, one of the local helio-seismology method, in order to comprehend the role of the flare in exciting the oscillation modes. We analyze these oscillations before, during and after the onset of the flare. The ratio of the mode parameters at different phases of the flare with respect to the pre-flare phase provides us with insight as to how the modes of oscillation are changing with the evolution of the flare. We find that in 32% of the cases studied, the power is absorbed almost completely in the active region. Out of the remaining 68%, a clear enhancement of the power is seen in 23% while a partial enhancement is seen in the other 45%.

This work is carried out through the National Solar Observatory Research Experiences for Undergraduate (REU) site program, which is co-funded by the Department of Defense in partnership with the National Science Foundation REU Program. The National Solar Observatory is operated by the Association of Universities for Research in Astronomy, Inc. (AURA) under cooperative agreement with the National Science Foundation.

155.05

Beyond the Limb: A Narrow Band EUV Search for Background Objects with the AIA Sam Schonfeld¹, P. Testa², S. Saar²

¹Whitman College, ²Harvard-Smithsonian Center for Astrophysics.

Exhibit Hall

As the star closest to Earth, the Sun provides us with the opportunity to study up close and test models for X-ray stellar activity. Its close proximity (and consequent brightness), however, makes it challenging to observe the Sun and other celestial objects with the same instrument; thus instrumental crosscalibration difficulties have complicated comparison of the Sun with other stars. The new Solar Dynamics Observatory (SDO) launched in February 2010 may at last allow for direct comparison of the Sun and other stars. The Atmospheric Imaging Assembly (AIA) onboard the SDO, a series of telescopes taking images of the full Sun at high spatial and temporal resolution in seven extreme ultraviolet (EUV) pass bands, can potentially observe background objects passing within the field of view of the telescopes off the limb of the Sun. Young stars, active galactic nuclei and other strong X-ray and EUV emitters may be bright enough to observe after careful background subtraction. Using technical specifications of the telescopes and measured X-ray fluxes of various background sources, we determined that with exposure times of the order of minutes, significantly longer than the standard ~3s exposure, we should be able to observe the brightest background sources when they pass in the AIA field of view. We also determined what kinds of instrumental limitations we need to overcome and how best to make observations of these dim background sources.

155.06

Improved Modeling Of Atmospheric Effects Of The September 1859 Solar Flare.

Keith Arkenberg¹, B. Thomas¹

¹Washburn University.

Exhibit Hall

The atmospheric effects of the 1859 solar flare known as the Carrington event have previously been studied by two different groups. In Thomas et al. 2007, the event was studied with a 2D atmospheric chemistry and dynamics model, using a proton fluence estimate derived from ice core records, and ionization scaled from the 1989 solar proton event. In Rodger et al. 2008, the Carrington event was studied using a 1D model, but with ionization calculated from a likely proton spectrum and time variation, based again on the 1989 event, as well as two other events. In this study we improve upon past work by combining the proton spectrum and time variation used in Rodger et al. 2008 with our 2D atmospheric model. This combination allows for a more accurate estimate of global, long-term atmospheric effects than either approach by itself. Here we report on our computation methods and results, including atmospheric ionization, production of odd nitrogen compounds and subsequent reduction in ozone. Finally, we compare these results to those of past studies.

155.07 The Heliophysics Event Knowledgebase in Action Neal E. Hurlburt¹

¹Lockheed Martin Corp..

Exhibit Hall

The Heliophysics Events Knowledgebase (HEK) system is being developed to help solar and heliospheric researchers locate features and events of interest to their science topics. After 9 months of operations using data from SDO we present an overview of the HEK system In action.

155.08

Using P-mode Oscillations of Infrared CO Lines to Probe the Solar Atmosphere $\mathsf{Erin}\ \mathsf{Cox}^1$

¹NSO.

Exhibit Hall

Using the 14 m vertical spectrograph on the NSO McMath-Pierce telescope, CO spectra of the Sun are obtained that are centered around 4.6 μ m. From these spectra, Gaussian fits are made to the 46664 Å line to acquire velocity, temperature and continuum parameters. With these parameters, full disk maps are made for each. By creating 3-D maps of velocity and temperature, p-mode oscillations are found by taking a power spectrum of both. Variations in power and central frequency with μ for the velocity map are found by taking power spectra at different annuli of μ . It is seen that power increases as μ increases. The next step is to measure the phase difference and coherence between the velocity and temperature maps, which will be presented. These are also found for different values of μ to better understand how CO changes higher in the solar atmosphere.

This work is carried out through the National Solar Observatory Research Experiences for Undergraduate (REU) site program, which is co-funded by the Department of Defense in partnership with the National Science Foundation REU Program. The National Solar Observatory is operated by the Association of Universities for Research in Astronomy, Inc. (AURA) under cooperative agreement with the National Science Foundation.

Early Results from the Atmospheric Imaging Assembly (AIA) on the Solar Dynamics Observatory (SDO) Theodore D. Tarbell¹, AIA Team

¹Lockheed Martin Advanced Technology Center.

Exhibit Hall

SDO was launched on February 11, 2010, and first light was in late March. AIA provides multiple simultaneous high-resolution full-disk images of the corona and transition region up to 0.5 R above the solar limb with 1.5" spatial resolution (0.6" pixels) and 10 second temporal resolution. AIA consists of four telescopes that employ normal incidence multilayer coated optics to provide narrow band imaging of seven EUV band-passes centered on specific lines: Fe XVIII (94 A), Fe VIII, XX, XXIII (131 A), Fe IX (171 A), Fe XII, XXIV (193 A), Fe XIV (211 A), He II (304 A), and Fe XVI (335 A). One telescope observes C IV (1600 A) and the nearby continuum (1700 A), and a filter that observes in the visible enables coalignment with images from other telescopes. The temperature diagnostics of the EUV emissions covers the range from 0.06M °K to 20M °K. Since early April, these images have been taken nearly continuously, usually with a cadence of 12 seconds. Although solar activity has only been increasing slowly in this cycle, there have been a large number of filament ejections that interact with large regions over the solar surface. In addition, because of the rapid cadence of images, a number of new wave phenomena have been discovered associated both with small flares and the interaction of expanding magnetic structures with pre-existing structures. Movies illustrating some of these events will be shown. AIA is supported by NASA (GSFC) contract NNG04EA00C at the Lockheed Martin Advanced Technology Center.

155.10

Analysis of Solar Transition Region Bright Points and Application to Existing Heating Models Norton B. Orange¹, H. M. Oluseyi¹, D. Chesny¹, C. Neira¹, L. Preuss¹, D. DeBoth¹, M. Ebert¹, L. Cohen¹ ¹Florida Institute of Technology.

Exhibit Hall

I have conducted an analysis on the spatial, spectral, and magnetic field data of bright point phenomena that occur in the Sun's upper transition region atmosphere. There are two main aspects to this study: an empirical study of the statistical distribution and properties of upper transition region bright points (UBPs) and a comparison of the measured quantities with theoretical models of their generation and characteristics. I also conducted a comparison of UBPs to other well-studied transition region (TR) phenomena such as blinkers, explosive events, and spicules. Our empirical study of UBPs is made possible through archived SOHO and Hinode data that contain full-disk images of the solar TR and corona with effective temperatures ranging from 0.10 MK to 2.0 MK. We measured surface densities, sizes, radiative outputs, Dopplergrams and magnetic structures of UBPs at 0.25 MK and 0.63 MK in the quiet Sun. The UBPs were modeled as hydrostatic loops to determine of volumetric heating rates. Comparison of the measured and modeled parameters suggest that magnetic reconnection is likely the dominate generation mechanism of UBPs, although MHD waves (or a combination of both) can not be ruled out.

Empirical Measurements of Loop Structures in the Sun's Transition Region Compared with Energy Balance Models

David Chesny¹, H. M. Oluseyi¹, N. B. Orange¹, D. DeBoth¹, L. Preuss¹, C. Neira¹, M. Ebert¹, L. Cohen¹ ¹*Florida Institute of Technology.*

Exhibit Hall

We have measured the properties of solar upper transition region loop structures barely resolvable in 1arcsecond resolution data from the Transition Region and Coronal Explorer (TRACE) satellite and from the Solar Ultraviolet Measurements of Emitted Radiation (SUMER) instrument aboard the SOHO satellite for the purpose of investigating the mechanisms that generate and energize these structures. The images were wavelet transformed to elucidate and isolate fine-scale loops, whose lengths, widths, emergent flux, flows, and underlying magnetic field were measured. It was found that the loops' magnetic geometries were well-fit by potential field models. However, hydrostatic models were unable to self-consistently reproduce the loop's observed properties for a wide range of parameter space.

155.12

Magnetic Cycles and Buoyant Magnetic Structures in a Rapidly Rotating Sun

Nicholas J. Nelson¹, B. P. Brown², S. Brun³, M. S. Miesch⁴, J. Toomre¹

¹University of Colorado-Boulder, ²University of Wisconsin-Madison, ³CEA-Saclay, France, ⁴High Altitude Observatory - NCAR.

Exhibit Hall

Observations of sun-like stars rotating faster than our current sun show that they exhibit solar-like magnetic cycles and features, such as star spots. Using global 3-D simulations to study the coupling of large-scale convection, rotation, and magnetism in a younger sun, we have probed the effects of more rapid rotation on stellar dynamos and the nature of magnetic cycles. Our anelastic spherical harmonics (ASH) code allows study of the convective envelope, occupying the outer 30% by radius of a sun-like star. Major MHD simulations carried out at three times the current solar rotation rate reveal magnetic dynamo action that can produce wreaths of strong toroidal magnetic field at low latitudes, often with opposite polarity in the two hemispheres. The presence of the wreaths is quite surprising, for they arise as quite persistent global structures amidst the vigorous and turbulent convection. We have recently explored behavior in systems with considerably lower diffusivities, achieved with a dynamic Smagorinsky treatment of unresolved turbulence. The lower levels of diffusion create magnetic wreaths that undergo prominent variations in field strength, even exhibiting global magnetic cycles that involve polarity reversals. Additionally, during the cycle maximum, when magnetic energies and mean magnetic fields peak, the wreaths possess buoyant magnetic structures that rise coherently through much of the convective envelope via a combination of advection by convective upflows and magnetic buoyancy. We explore aspects of these rising magnetic structures and the evolving global dynamo action which produces them.

156 *The Solar System* Poster Session *Exhibit Hall*

156.01 VLBA Astrometry of Cassini

Dayton L. Jones¹, J. Border¹, V. Dhawan², W. Folkner¹, E. Fomalont², R. Jacobson¹, G. Lanyi¹, J. Romney² ¹*JPL/Caltech*, ²*NRAO*.

Exhibit Hall

We have carried our a series of Very Long Baseline Array (VLBA) astrometric observation of the Cassini spacecraft, which is currently orbiting Saturn, to determine the position of Saturn's center of mass in the International Celestial Reference Frame (ICRF). Our positional accuracies are typically 0.2-0.3 milliarcseconds, corresponding to about 2 km at the distance of Saturn. The goal of the project is to improve the Saturn ephemeris. This paper reports the results of our first eight epochs of observing, from October 2006 through April 2009. A new planetary ephemeris (DE 422) has been fit to these data, plus two earlier VLBA observations of Cassini by others and a Cassini-based VLBA gravitational deflection experiment by Fomalont et al. in February 2009. Post-fit residuals for DE 422 have a mean offset less than 0.2 mas in both coordinates, but not all of our phase reference sources have ICRF position with this accuracy yet. Future observations will improve reference source positions, and will continue to follow Saturn through more than 1/4 of its orbital period. (The Cassini mission is currently funded to operate until 2017.) We are grateful to Larry Teitelbaum for support of this project through the Advanced Tracking and Observational Techniques of JPL's Interplanetary Network Directorate, and to John Benson and the VLBA operations team at NRAO for their excellent support of these observations. The VLBA is a facility of the National Radio Astronomy Observatory, which is operated by Associated Universities, Inc., under a cooperative agreement with the National Science Foundation. Part of this research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

156.02

Quantifying Uncertainties in the Evolution of the Solar Flux

John Sheets¹, M. Claire¹, I. Ribas²

¹University of Washington, ²Institut de Ci`encies de l'Espai, Spain. Exhibit Hall

Understanding changes in the solar flux over geologic timescales is essential to studies of planetary atmospheres and how planets evolve in general. To this end, we have developed quantitative estimates of the wavelength-dependent solar flux over time. Using multi-wavelength data from the Sun and solar analogs we present a parametrization of the solar flux which is nominally valid from 2-20000 nm, and from ~0.02 through 7.1 Gyr.

The parameterization is subject to large uncertainties inherent in primary measurement error, the unknown ages of the solar proxies, and the intrinsic variability of the solar analogs. This poster details our procedures in quantifying the effect of these uncertainties on our estimates of the evolving solar flux. From the X-ray to the near UV, we derived thousands of different power law fits to the observational data via a Monte Carlo simulation. During each iteration of the simulation, an age for each solar analog was selected randomly from age ranges found in the literature. These ages are fit against the observational data, which are themselves randomized by their measurement errors and assumed intrinsic variability. This produces multiple power laws fits for flux versus time in various wavelength regimes and strong lines, which we compare against fits assuming exact ages and flux values.

We find the integrated mean error (standard deviation / mean) of our Monte Carlo simulations to never be in excess of 100%, with significant decreases in error at older stellar ages. The mean absolute error on any flux value from any wavelength is never above 50%. We therefore submit our model of the solar flux as viable for planetary atmosphere studies which are concerned with the first order evolution of the Sun in time.

156.03

Analysis Of *Spitzer* IRS 5.6 To 7.7 μm Observations Of Comets 6P/d'Arrest And C/2007 N3 (Lulin) David Emerson Harker¹, C. E. Woodward², M. S. Kelley³, D. Bockelee-Morvan⁴, J. Crovisier⁴, D. H. Wooden⁵

¹UC, San Diego/CASS, ²Univ. of Minnesota, ³Univ. of Maryland, ⁴LEISA, Observatoire de Paris, France, ⁵NASA Ames.

Exhibit Hall

The production rate of volatiles from comet nuclei through sublimation of ices is a measure of the activity and volatile abundance. Sublimation of water, the dominant ice in cometary bodies, is the main source of activity at heliocentric distances $r_h < 3$ AU from the Sun. The water production rate ($Q(H_2O)$), the rotational temperature (T_{rot}) and the ortho-to-para ratio (OPR) are of particular interest in the study of cometary atmospheres and cometary physics, and cometary origins. We present *Spitzer* IRS 5.6 to 7.7 µm spectra of comets 6P/d'Arrest (6P) obtained 2008 Sept 12 UT (post-perihelion; $r_h = 1.39$ AU), and C/2007 N3 (Lulin) obtained 2008 Oct 04 UT, (pre-perihelion; $r_h = 1.90$ AU). The 6.3 µm v₂ vibrational band is detected in both comets. Both comets also show an as yet unidentified broad feature at ~7.2 µm that appears in other IRS observations of comets. Fluorescence models of water emission are used to calculate $Q(H_2O)$, T_{rot} , and OPR towards the nucleus of both comets and into the coma ~9" and ~18" away from the nucleus to assess the coma spatial distribution of T_{rot} , and the OPR. Limits are placed on emission from controversial cometary constituents, carbonates and PAHs.

Support for this work is provided in part by NASA through contract 1355318.

156.04

Modeling the Interior Structure of Tempel 1

Victoria Hartwick¹, G. Sarid²

¹University of Wisconsin - Madison, ²Institute for Astronomy. Exhibit Hall

Processes that determine the correlation between nuclear activity and coma structure in comets are largely unknown. Since ground based observations of comet nuclei are impossible, complex models present the best current method for interpreting coma changes during orbit, with the exception of in situ observations. Using data collected from the Deep Impact mission in 2005 and ground based observations from 1983 to 2005, we present a preliminary model of the interior activity of Tempel 1. Matching of output production rates to observed production rates provides information about the model's accuracy.

156.05

Efficient Prediction of Asteroid Positions from Solar System Models

Yusra AlSayyad¹, S. Krughoff¹, A. J. Connolly¹, L. Jones¹, T. Budavari², B. Howe¹

¹University of Washington, ²Johns Hopkins University.

Exhibit Hall

When simulating the distribution of sources across the night sky, querying for stationary objects, such as galaxies, is relatively simple. For moving objects, such as near earth objects (NEOs) and main belt asteroids (MBAs), this becomes increasing more complex. Each family of solar system objects has a range of abundances and speeds through ra/dec space. For example, MBAs are plentiful (~10⁷) but move

slowly (< 1 deg/day), and NEOs are rare (~10⁵) but can move up to 70 deg/day. How do we optimally store and query all families of moving objects? We describe performance results and experiences using different methods, such as storing bounding boxes for the trajectories, and spatial abstraction tools, such as MSSQL geospatial support and SkyServer's HTM index and library of spatial constructs. We apply these results to simulations of the data flow from the Large Synoptic Survey Telescope with the goal of querying simulated catalogs quickly for a list of objects that would appear in the LSST's circular aperture at a given pointing and epoch.

156.06

Asteroid Astrometry Accuracy

Hugh C. Harris¹, M. A. Murison¹

¹U.S. Naval Obs..

Exhibit Hall

Predictions of asteroid (or comet) positions depend on the accuracy of their orbits, and in turn on the history and quality of their measured postitions as they move around the sky. Currently the error of a single observation is limited by catalog errors of ~50 mas, even with the best available catalogs such as Tycho or UCAC. We discuss errors in catalogs, asteroid orbits, and predicted positions for bright asteroids (V < 17), including the 6000 asteroids being monitored by the Flagstaff Astrometric Scanning Transit Telescope. For purposes of predicting occultations, it is desirable to improve asteroid orbits and the positions of the occulted stars. We discuss an experiment to greatly reduce the error of their relative positions, and improve the predicted occultation path.

This work received funding from NASA NNH08AI17I.

156.07

The Impact Of The Lcross Satellite With The Moon As Seen By The Hubble Space Telescope Alex Storrs¹, L. Guillou¹, A. O'Hara¹

¹Towson Univ..

Exhibit Hall

We present Hubble Space Telescope (HST) images and NUV spectra of the near lunar region at the time of the impact of the LCROSS experiment (Colaprete 2007) into a permanently shadowed crater on the lunar south pole. Images immediately before and after the impact show an enhancement in the scattered light near 300 nm within a minute of the event. Spectra show persistent emission of the OH (1-0) band at 283 nm, which may indicate a permanent lunar exosphere of OH as reported by Sridharan et al (2010), rather than OH produced by photolysis of water liberated by the impact event. Analysis of the data is limited by uncertainty in the HST pointing, as the observations were made under gyro control.

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Jupiter In The Crosshairs: Recent Impacts And Their Implications

Heidi B. Hammel¹, I. de Pater², A. A. Simon-Miller³, L. Fletcher⁴, M. B. Boslough⁵, G. S. Orton⁶, G. Djorgovski⁷, P. Yanamandra-Fisher⁶, M. H. Wong², R. Hueso⁸, A. Sánchez-Lavega⁸, C. Go⁹, A. Wesley¹⁰, S. Pérez-Hoyos⁸, M. Edwards¹¹, J. T. Clarke¹², K. S. Noll¹³

¹Space Science Institute, ²UC Berkeley, ³NASA's GSFC, ⁴Oxford, United Kingdom, ⁵Sandia, ⁶JPL, ⁷Caltech, ⁸Univ. del Pais Vasco, Spain, ⁹U. San Carlos, Philippines, ¹⁰Acquerra Pty. Ltd., Australia, ¹¹Gemini, Chile, ¹²Boston U., ¹³STScI.

Exhibit Hall 156.09

Effective Mitigation of a Potentially Hazadous Objtect by a Subsurface Explosion

Robert Weaver¹, C. Plesko¹, W. Dearholdt¹

¹LANL.

Exhibit Hall

Disruption or mitigation of a potentially hazardous object (PHO) by a high-energy subsurface burst is considered. This is just one possible method of impact-hazard mitigation. We present xRAGE hydrocode models of the shock-generated disruption of PHOs by subsurface nuclear bursts using scenario-specific models from realistic RADAR shape models. We will show 2D and 3D models for the disruption by a large energy source at the center of such PHO models (~100 kton - 10 Mton) specifically for the shape of the Itokawa asteroid. We study the effects of non-uniform compistion (rubble pile), effective source energy, and the optimal depth of burial from the surface explosion to the central explosion.

156.10

Investigating the Dynamical History of the Solar System

Schuyler Wolff¹, R. Murray-Clay², R. Dawson³

¹Western Kentucky University, ²Smithsonian Astrophysical Observatory, ³Harvard University. Exhibit Hall

The current dynamical structure of the Kuiper belt was shaped by the evolution of giant planet orbits during the era of planet formation. Numerical models of this process, while reproducing many properties of the belt, have difficulty generating the high inclinations and eccentricities observed for some objects while maintaining a low eccentricity and low inclination "cold classical" population. We present a parameter study of the effect of different dynamical histories on orbits in the Kuiper belt using N-body simulations. In particular, we probe which combinations of migration, eccentricity damping, and inclination damping of Neptune over the history of the solar system allow the cold classical population to survive. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 0754568 and by the Smithsonian Institution.

156.11

Rotation Rates of 8 Main Belt Asteroids

Dicy Ann E. Saylor¹, M. A. leake²

¹University of Georgia, ²Valdosta State University.

Exhibit Hall

We report the rotation rates of the 8 main-belt asteroids 205 Martha, 252 Clementina, 506 Marion, 567 Eleutheria, 613 Ginevra, 869 Mellena, 996 Hilaritas, and 1490 Limpopo and discuss future work. These bodies include one P and seven C-class asteroids located at heliocentric distances of 2.3 to 3.6 AU. Seven of the light curves produced useful results; three of the periods are reported here for the first time, one expands on a previous publication, and the remaining three periods support previously published results. The study of main belt asteroids is an important topic because they can give us insight into

planet formation and evolution. The focus of this paper is to use photometry to learn rotation periods. Future work will focus on using this information to obtain shape and pole orientation. Knowing the rotation rate, shape and orientation and their dynamics can place constraints on the early solar system. This project was funded by the National Science Foundation Research Experiences for Undergraduates (REU) program through grant NSF AST-1004872.

156.12

Physical Characterization of the Binary Asteroid 66146 (1998 Tu3)

Thien-Tin Truong¹, M. Hicks², D. Mayes², T. Barajas³, K. Garcia¹

¹California State University - LA, ²Jet Propulsion Laboratory California Institute of Technology, ³Los Angeles City College.

Exhibit Hall

The near-Earth asteroid 66146 (1998 TU3) was discovered on 1998 October 13 by the LINEAR NEO survey (MPEC 1998-U03). We obtained five nights of Bessel BVRI observations (2010 Aug 6,7,10,12,13 UT) and one night of Bessel R (August 8 PST) at the JPL Table Mountain Observatory (TMO) 0.6-m telescope near Wrightwood, California. These observations were obtained as part of our ongoing survey at TMO of Potentially Hazardous Asteroids (PHAs), planetary radar targets, and low delta-V near-Earth asteroids (NEOs).

The object's rotationally averaged colors (B-R=1.238+/-0.011 mag; V-R=0.440+/-0.008 mag; R-I=0.275+/-0.010 mag) were found most compatible with an Sk-type spectral classification (Bus Taxonomy)/S-type (Tholen Taxonomy). This association was obtained through a comparison of our colors with the 1341 asteroid spectra in the SMASS II database (Bus & Binzel 2002). Our classification differs significantly from the Q-type taxonomy reported by Whitely (2002).

Assuming a solar phase parameter g=0.15 we performed a period search using standard Fourier techniques. We found a best-fit rotational period P_{syn} =2.378+/-0.001 hr, in excellent agreement with the 2.3779+/-0.0004 period determined by Richards et al. (2007). The dispersion in the phased single period lightcurve strongly suggests that 1998 TU3 is be a binary system, with variations in observed flux caused by an unresolved, tidally locked secondary companion. Fitting a 2-period model as described by Pravec et al. (2000), we found that our photometry agrees well with a binary model (P₁=2.378+/-0.01 hr, P₂=28.28+/-0.05 hr).

We have three additional nights scheduled for this object at TMO (Oct 8, 9, 10 2010 UT), extending our solar phase coverage and allowing us to refine our rotational models. 1998 TU3 will experience an exceptional apparition in 2012. This object may be a good candidate for shape/pole modeling via lightcurve inversion, especially if photometry can be obtained from both northern and southern hemispheres. We welcome any potential collaborations.

157 *Instrumentation: Ground Based or Airborne* Poster Session *Exhibit Hall*

157.01 Monitoring High Energy Transients With Crro Tiffany Watkins¹, D. Macomb¹, J. Norris² ¹Boise State University, ²University of Denver. Exhibit Hall

We describe the capabilities and early results from a newly developed optical observatory, the Challis Rapid Reaction Observatory (CRRO). Our initial nightly observing program concentrates on blazars, accreting binaries and gamma-ray bursts. The CRRO is located in central Idaho at 2165 m (7100 feet)

elevation, in a mountain desert micro-climate that enjoys the driest (~ 5" yearly precipitation) and clearest nights in the State. It is completely remotely operable, with all necessary capabilities for automated operation in response to GRB alerts. This facility adds materially to the U.S. geographic coverage for GRB afterglows, being the only automated, remotely operable facility in the northwest part of the country.

157.02

EVLA Commissioning: Status and Prospects

Michael P. Rupen¹, EVLA Scientific Commissioning Team

¹NRAO.

Exhibit Hall

We report progress in commissioning the Expanded Very Large Array (EVLA), a project to improve the key observational capabilities of the VLA (point source sensitivity, instantaneous bandwidth, frequency resolution, and flexibility) by roughly an order of magnitude, while extending the suite of receivers to allow tuning the array anywhere between 1 and 50 GHz. The first scientific data were taken on March 2, 2010, and commissioning and scientific operations continue at a rapid pace. Here we report on the status of the upgrades and present some recent observational results. We also review the schedule through the end of the construction/commissioning period with special emphasis on the scientific capabilities we expect to offer the community. Full operations are scheduled to begin at the end of 2012.

The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

157.03

Michi: A MIR Instrument Concept for the TMT

Christopher C. Packham¹, Y. K. Okamoto², A. Tokunaga³, J. Carr⁴, M. Chiba⁵, M. Chun³, K. Enya⁶, H. Fujiwara⁶, T. Fujiyoshi⁷, M. Honda⁸, M. Imanishi⁷, Y. Ita⁵, H. Kataza⁹, T. Kotani⁹, H. Izumiura¹⁰, N. A. Levenson¹¹, T. Matsuo¹², M. Matsuura¹³, T. Minezaki¹⁴, J. Najita¹⁵, T. Onaka¹⁴, T. Ootsubo⁵, M. Richter¹⁶, I. Sakon¹⁴, M. Takami¹⁷, C. M. Telesco¹, C. Warner¹, C. M. Wright¹⁸, T. Yamashita¹²

¹Univ. of Florida, ²Univ. of Ibaraki, Japan, ³Univ. of Hawaii, ⁴NRL, ⁵Univ. of Tohoku, Japan, ⁶ISAS, Japan, ⁷Subaru Observatory, ⁸Univ. of Kanagawa, Japan, ⁹ISAS/JAXA, Japan, ¹⁰NOAJ, Japan, ¹¹Gemini Observatory, Chile, ¹²NAOJ, Japan, ¹³UCL, United Kingdom, ¹⁴Univ. of Tokyo, Japan, ¹⁵NOAO, ¹⁶UC Davis, ¹⁷ASIAA, Japan, ¹⁸UNSW, Australia.

Exhibit Hall

A mid-infrared (MIR) imager and spectrometer is under consideration for construction in the first decade of the Thirty Meter Telescope's (TMT) operation. When combined with a MIR adaptive optics system, the instrument will afford 15 times higher sensitivity, 4 times better spatial resolution (0.08") than 8m-class telescopes, and ~4.5 times better spatial resolution than the JWST. Additionally, its huge light gathering power opens a new window of high-dispersion spectroscopy in the MIR. We discuss the key science drivers, from star and planet formation to galaxies and black holes and cosmology; science drivers which are in close synergy with the recent Astro 2010 Decadal Survey report. We flow down our science cases to produce fundamental and optional instrument capabilities, including imaging, long-slit and IFU spectroscopy, and polarimetry.

Early Science Planning of Protoplanetary Disks and Protostars in the Orion Nebula Cluster Using SOFIA/FORCAST

Keri Hoadley¹, J. D. Adams², T. L. Herter², G. Gull², C. Henderson², J. Schoenwald², L. Keller³, T. S. Megeath⁴

¹Florida Institute of Technology, ²Cornell University, ³Ithaca College, ⁴University of Toledo. Exhibit Hall

The Faint Object Camera for the SOFIA Telescope (FORCAST) is a mid-infrared facility instrument for the Stratospheric Observatory For Infrared Astronomy (SOFIA). In late May of this year, FORCAST achieved first light on SOFIA during a Telescope Assembly characterization flight, successfully taking photometry of Jupiter, its moons, and M82 from an altitude of 35,000 ft. Analysis of images of Jupiter and one of its moons, Ganymede, show the in-flight sensitivity to be comparable to that expected from preflight (lab) measurements and models.

In preparation for SOFIA Short Science, we constructed Spectral Energy Distributions (SEDs) for known proplyds and protostars (Smith et al. 2005) in the core of the Orion molecular cloud using 2MASS (Skrutskie et al. 2006), IRAC on Spitzer, TReCS on Gemini South (Smith et al. 2005), and 880mm SCUBA data (Mann and Williams 2009). FORCAST will provide important wavelength coverage (20 - 40 microns) which when used in conjunction with previous data will constrain the physical properties of the proplyds and protostars. We fit the observed SEDs with those from radiative transfer models for circumstellar disks and protostars from Robitaille et al (2006, 2007). With these models, we can extrapolate into the 20 - 40 micron region of FORCAST and determine the range of models that FORCAST is capable of detecting. Using the FORCAST sensitivity model and the SEDs of known proplyds, we expect to detect 67% of the proplyds found by other investigations. However, detectability will be greatly influenced by the presence of structures in the diffuse dust emission associated with the HII region complex. Comparing FORCAST observations with the radiative transfer models will help to understand the physical properties of proplyds and protostars, and perhaps illuminate the impact of their environments, such as photoevaporation of disks and effects from crowding.

157.05

Simultaneous Lidar and All-Sky IR Camera Observations to Measure Cloud Transmission

Peter C. Zimmer¹, J. Sebag², J. T. McGraw¹, D. C. Zirzow¹, D. V. Vorobiev¹, UNM Measurement Astrophysics (MAP) Research Group

¹Univ. of New Mexico, ²NOAO.

Exhibit Hall

We present initial results of combined lidar and all-sky thermal infrared camera measurements of transmission losses through clouds. Thermal IR observations in the 10 micron window have long been used at observatories to detect the presence of clouds by measuring the contrast in downwelling thermal radiation between clear and cloudy sky. The ability of these techniques to measure thin cirrus at high altitudes, the sort of clouds that typically ruin otherwise photometric conditions, has always been limited due to their low temperature and low emissivity. Lidar, on the other hand, is quite effective at measuring both the presence and optical depth of thin cirrus clouds, well below 1% transmission losses. A lidar can only operate in one direction at a time and thus is limited in its ability to measure transmission over wide fields of view. The combination of wide field thermal IR imaging plus lidar measurements of transmission hold significant promise for helping solve the time and field dependence of atmospheric transmission caused by clouds, especially sub-visual cirrus.

To test this instrumental combination, the LSST all-sky infrared camera was deployed for several weeks at the UNM Campus Observatory in Albuquerque, NM, the location of the Astronomical Lidar for Extinction (ALE). The two instruments were operated together under various cloud cover conditions and

when conditions permitted, narrowband photometry of bright stars was simultaneously obtained to verify the temporal and spatial variation of extinction.

MAP atmospheric transmission research is supported by NIST Award 60NANB9D9121 and NSF Grant AST-1009878.

157.06

Generic Misalignment Aberration Patterns in Wide-Field Telescopes

Rebecca Sobel¹, P. L. Schechter¹

¹MIT.

Exhibit Hall

Aligned telescopes either produce third-order Seidel aberrations or are specifically designed to balance them out. These Seidel aberrations manifest in the field as patterns of point spread functions. When optics are misaligned, breaking the axial symmetry of the telescope, another set of generic third-order aberration patterns arise, one each for coma, astigmatism, and curvature of field, and two for distortion. Each misalignment pattern is characterized by a two dimensional vector, which is in turn a linear combination of the mirror tilts and decenters. For an N-mirror telescope, 2(N-1) patterns must be measured to keep the telescope aligned. Common practice for two mirror telescopes is to use misalignment coma and astigmatism patterns to align the secondary mirror. However, for three mirror telescopes, it will be necessary to either measure the curvature of field and one of the distortion patterns, or alternately to measure smaller fifth order misalignment patterns in order to maintain alignment.

This work was supported by the National Science Foundation through a Graduate Research Fellowship.

157.07

The Infrared Camera for RATIR, a Rapid Response GRB Followup Instrument

David A. Rapchun¹, W. Alardin², B. C. Bigelow³, J. Bloom⁴, N. Butler⁴, A. Farah², O. D. Fox⁵, N. Gehrels⁶, J. Gonzalez², C. Klein⁴, A. S. Kutyrev⁷, G. Lotkin¹, C. Morisset², S. H. Moseley⁶, M. Richer², F. D. Robinson⁸, M. V. Samuel⁶, L. M. Sparr⁶, C. Tucker¹, A. Watson²

¹NASA/GSFC/GST, ²University of Mexico, Mexico, ³University of California, Santa Cruz, ⁴University of California, Berkeley, ⁵NASA/GSFC/ORAU, ⁶NASA GSFC, ⁷NASA/GSFC/CRESST, ⁸NASA/GSFC/Orbital. Exhibit Hall

RATIR (Reionization and Transients Infrared instrument) will be a hybrid optical/near IR imager that will utilize the "J-band dropout" to rapidly

identify very high redshift (VHR) gamma-ray bursts (GRBs) from a sample of all observable Swift bursts. Our group at GSFC is developing the instrument in collaboration with UC Berkeley (UCB) and University of Mexico (UNAM). RATIR has both a visible and IR camera, which give it access to 8 bands spanning visible and IR wavelengths. The instrument implements a combination of filters and dichroics to provide the capability of performing photometry in 4 bands simultaneously. The GSFC group leads the design and construction of the instrument's IR camera, equipped with two HgCdTe 2k x 2k Teledyne detectors. The cryostat housing these detectors is cooled by a mechanical cryo-compressor, which allows uninterrupted operation on the telescope. The host 1.5-m telescope, located at the UNAM San Pedro Martir Observatory, Mexico, has recently undergone robotization, allowing for fully automated, continuous operation. After commissioning in the spring of 2011, RATIR will dedicate its time to obtaining prompt follow-up observations of GRBs and identifying VHR GRBs, thereby providing a valuable tool for studying the epoch of reionization.

The Balloon Experimental Twin Telescope for Infrared Interferometry (BETTII): High Angular Resolution in the Far-Infrared

Stephen Rinehart¹

¹NASA's GSFC.

Exhibit Hall

Astronomical studies at infrared wavelengths have dramatically improved our understanding of the universe, and observations with Spitzer, Herschel, and SOFIA will continue to provide exciting new discoveries. The relatively low angular resolution of these missions, however, is insufficient to resolve the physical scale on which mid-to far-infrared emission arises, resulting in source and structure ambiguities that limit our ability to answer key science questions. Interferometry enables high angular resolution at these wavelengths - a powerful tool for scientific discovery. We are building the Balloon Experimental Twin Telescope for Infrared Interferometry (BETTII), an eight-meter baseline Michelson stellar interferometer to fly on a high-altitude balloon. BETTII's spectral-spatial capability, provided by an instrument using double-Fourier techniques, will address key questions about the nature of disks in young star clusters and active galactic nuclei and the envelopes of evolved stars. BETTII will also lay the technological groundwork for future balloon programs, paving the way for interferometric observations of exoplanets.

157.09

The Magdalena Ridge Interferometer: Telescope Delivery to Laboratory Fringe Measurements

Colby Jurgenson¹, F. Santoro¹, A. Olivares¹, R. Selina¹, I. Payne¹, M. Creech-Eakman¹, D. Buscher², C. Haniff², J. Young²

¹NMT/MRO, ²University of Cambridge, United Kingdom.

Exhibit Hall

This report focuses on recent developments at the Magdalena Ridge Observatory Interferometer (MROI) in three major areas: 1) telescope delivery and array infrastructure construction, 2) installation of the first vacuum delay line and 3) laboratory fringe measurements with the first fringe beam combiner. Construction of the telescope foundations and utilities began in August of 2010 and will be complete in September of 2011 for delivery of the first of ten telescopes. The MROI now has the longest (100m) evacuated fast delay line in the world. Initial performance tests that began in November of 2010 are reported here. First broadband fringe measurements have been recorded in the laboratory with the fringe tracking beam combiner. These measurements demonstrate high optical quality, and visibilities matching the predicted values for its architecture type.

157.10

The Willard L. Eccles Observatory: Preliminary Characterization of the Site for Optical Astronomy Nic Ramsrud¹, K. Dawson¹, D. Della Corte¹, P. Gondolo¹, P. Ricketts¹, U. Samarasingha¹, W. Springer¹ ¹University of Utah.

Exhibit Hall

The University of Utah Department of physics and Astronomy recently completed construction of the Willard L. Eccles Observatory, a new facility on the edge of the Great Basin desert in western Utah. Located between Las Vegas and Salt Lake City, the site was chosen after careful consideration of climate, light pollution, seeing quality, and available infrastructure. The observatory is located on a prominent peak at an altitude of 9551 feet and houses a 0.8 meter optical telescope from DFM Engineering. The first images taken with the telescope have produced sub-arcsecond seeing and minimal sky background as would be expected for this remote site. We will present a description of the observatory and a preliminary characterization of the site.

The construction of this observatory was made possible by the generous support of the Willard L. Eccles Foundation and the Katherine W. and Ezekiel R. Dumke, Jr. Foundation.

157.11

Robo-AO: The First Autonomous Laser Guide Star Adaptive Optics System for Small Telescopes Reed L. Riddle¹, C. Baranec¹, A. N. Ramaprakash², N. Law³, S. Tendulkar¹, S. Kulkarni¹, K. Bui¹, M. Burse², P. Chordia², H. Das², R. Dekany¹, M. Kasliwal¹, E. Ofek¹, J. Zolkower¹

¹California Institute of Technology, ²Inter-University Centre for Astronomy and Astrophysics, India, ³University of Toronto, Canada.

Exhibit Hall

Robo-AO will be the first fully autonomous laser guide star adaptive optics and science system. Specifically designed to take advantage of small (1 to 3 meter) telescopes, Robo-AO will deliver high angular resolution science in the visible and near infrared for up to hundreds of targets per night. This will enable the exploration of science programs not practical for larger aperture adaptive optics systems. This presentation discusses the current status of the Robo-AO project, including the laboratory testbed, laser guide star facility and plans for a demonstration of the fully autonomous system next year.

157.12

Zodiac: A Balloon Facility for Exoplanet Debris Disk Observations

Stephen C. Unwin¹, W. Traub¹, G. Bryden¹

¹JPL.

Exhibit Hall

Zodiac is a telescope-coronagraph system, operating at visible wavelengths, mounted on a balloonborne gondola in the stratosphere. The science objective is to image debris disks around nearby stars. Debris disks, usually found in the outer reaches of a planetary system, are significant for exoplanet science because (a) they tell us that planet formation did actually get started around a star, (b) they are a contributing source of potentially obscuring dust to the inner part of the disk where we will someday start searching for terrestrial planets, and (c) for a disk with an inner edge, this feature is a signpost for a shepherding planet and thus a sign that planet formation did indeed proceed to completion around that star.

The telescope has a 1-m diameter, clear-aperture primary mirror, designed to operate in the cold stratospheric environment. The coronagraph is designed to suppress starlight, including its diffracted and scattered components, and allow a faint surrounding debris disk to be imaged. We will control the speckle background to be about 7 orders of magnitude fainter than the star, with detection sensitivity about one more order of magnitude fainter, in order to comfortably image the expected brightness of typical debris disks. Zodiac will be designed to make scientifically useful measurements on a conventional overnight balloon flight, but would also be fully compatible with future Ultra Long Duration Balloon flights. Zodiac has a technical objective of advancing the technology levels of future mission components from the lab to near-space flight status. These components include deformable mirrors, wavefront sensors, coronagraph masks, lightweight mirrors, precision pointing, and speckle rejection by wavefront control.

The research described in this talk was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration. Government sponsorship acknowledged.
A Summary of the First Year of Observations from the West Mountain Observatory 0.9-meter Telescope

Michael D. Joner¹, E. G. Hintz¹, C. D. Laney¹, J. W. Moody¹

¹Brigham Young Univ..

Exhibit Hall

We present a summary of selected projects that have made use of the new 0.9-meter telescope located at the Brigham Young University West Mountain Observatory during its first year of operation. Projects are limited to direct imaging but include a wide variety of subjects. Targets include intrinsic variable stars, standard star photometry, narrow band imaging studies, and long term monitoring of various objects such as high mass X-ray binaries, active galactic nuclei, pre-main sequence objects, and Cepheid variable stars. The use of filters with excellent transmission characteristics, along with a high quantum efficiency CCD, has greatly extended the effective limiting magnitude for this system.

The 0.9-meter telescope was made possible through a grant from the National Science Foundation PREST program (AST-0618209). We also acknowledge continued support from the Brigham Young University Department of Physics and Astronomy for continued operational funding and research support at the West Mountain Observatory.

157.14

Progress to First Light for AMASING, an Aperture Masking Instrument

Luke M. Schmidt¹, F. G. Santoro², C. A. Jurgenson²

¹New Mexico Tech, ²Magdalena Ridge Observatory, New Mexico Tech.

Exhibit Hall

We report on construction progress for the AMASING (Aperture Masking And Speckle ImagiNG) instrument. AMASING is designed for aperture masking and speckle interferometry at optical wavelengths. This report will focus on three main aspects of the instrument construction. The optical and electronic components have been selected and are assembled in a laboratory. We describe the optical alignment procedures and expected visibility performance across the design wavelengths as well as a discussion on the types of aperture masks developed for the instrument. The support structure and enclosure have been designed to provide a stable platform for the instrument optics. We document the construction, predicted performance and the procedure for aligning the structure with the optical axis of the telescope. Finally we discuss the instrument software control architecture and interface with the telescope.

This work has been supported by LANL-NMT MOU UCDRD funding, a College Cost Reduction and Access Act grant to Amarillo College, the New Mexico Space Grant Consortium and the New Mexico Tech Graduate Student Association Matuszeski Research Grant.

157.15

NIST-traceable SI Calibration of Standard Stars

John T. McGraw¹, P. C. Zimmer¹, D. C. Hines², J. T. Woodward³, C. E. Cramer³, K. R. Lykke³, S. W. Brown³, A. W. Smith³, G. T. Fraser³, C. W. Stubbs⁴, A. B. Hull¹, D. C. Zirzow¹, D. V. Vorobiev¹, Measurement Astrophysics Research Team

¹Univ. of New Mexico, ²Space Telescope Science Institute, ³NIST, ⁴Harvard University. Exhibit Hall

We describe optical spectrophotometric observing techniques for bright stars, and two independent procedures for calibrating these observations to NIST-calibrated detectors, resulting in absolute spectral energy distributions in SI irradiance units of W/m²/nm.

Stars, thermal point sources with physically well understood structures and atmospheres, radiate from

the ultraviolet to the infrared and thus provide excellent radiometric standards against which to compare and calibrate ground- and space-based astronomical observations. We have evolved techniques for ground-based standardization of the spectral energy distributions of stars from 350 nm to 1050 nm for an initial set of standard stars with V < 5.5.

With adequate photometric and spectrophotometric vetting, stable standard star candidates can be identified. The Measurement Astrophysics (MAP) standardization technique uses a unique objective spectrometer supported by an atmospheric extinction-sensing lidar for the stellar observations. The spectrometer is calibrated using two separate NIST detector-based standardization techniques. The first is implemented by observing a far-field, point-like NIST spectrophotometrically monitored source approximately one kilometer distant, and the second uses a near-field collimated source illuminated wavelength-by-wavelength using a monochrometer. We describe in detail the calibration procedures and analyze the utility of calibrating astronomical standard stars using two independent procedures. MAP standard star research is supported by NIST Award 60NANB9D9121 and NSF Grant AST-1009878.

157.16

Deriving Telescope Properties Using Daytime Sky Observations

Shannon Hall¹, D. Harrington²

¹Whitman College, ²University of Hawaii.

Exhibit Hall

High-resolution spectropolarimetry in night-time astronomy is a relatively new but powerful remote sensing technique. In order to make accurate spectropolarimetric measurements using large telescopes it is necessary to derive the calibration of the telescope by recovering the Mueller matrix elements. These calibrations are typically difficult to recover and are functions of wavelength and telescope pointing. We demonstrate a novel technique using observations of the bright, highly polarized, and easily accessible daytime sky. With the calibration of the AEOS 3.67m telescope on Haleakala and the new low-resolution spectropolarimeter LoVIS we illustrate the spectropolarimetric accuracy with observations of AB Aurigae.

157.17

Evolving Technology for Fabricating 1 to 3.5 meter Optics for New Generations of Ground-based Telescopes

Blaise Canzian¹, A. Clarkson¹, F. Piche¹, J. B. Barentine², J. Daniel², T. Hull² ¹L-3 Communications/ Brashear, ²L-3 Communications/ Tinsley.

Exhibit Hall

The advent of new requirements for intermediate and large telescopes has been accompanied by development of new processes and equipment to fabricate optics associated with these telescopes. We will discuss powerful new optical processing solutions that are being demonstrated. These methods offer extreme optical convergence of aspheric forms achieving demanding surface structure functions. Affected areas of astronomical telescope architecture include methods for rapid processing of segmented mirrors, and production of meniscus mirrors. We discuss finish and test of large turning flats as well as on-axis and off-axis aspheric primary and secondary mirrors. Furthermore, methods are now available to nearly fully mitigate substructure print-through of advanced lightweighted mirrors. Emerging optical fabrication solutions enlarge the design space for new generations of advanced astronomical telescopes.

Current Status of MMT Polarimeter (MMTPol)

Megan M. Krejny¹, K. Dewahl¹, T. J. Jones¹, C. Packham², C. Warner¹

¹University of Minnesota, ²University of Florida.

Exhibit Hall

We present a progress report for MMTPol, an imaging polarimeter operating at 1-5 microns on the MMT telescope. MMTPol will work in conjunction with the adaptive optics secondary to produce images with high spatial resolution and polarimetric precision, making it ideal to observe phenomena such as protoplanetary disks, AGN and comets. We discuss the design and construction of the optics and cryogenics systems. We present results from the initial installation of the science grade detector array. Finally, we discuss the hexapod mount used to integrate MMTPol with the telescope.

157.19

The Productivity and Impact of Large Optical Telescopes Dennis Crabtree¹

¹NRC-HIA, Canada.

Exhibit Hall

The primary scientific output from an astronomical telescope is the collection of papers published in refereed journals. A telescope's productivity is measured by the number of papers published which are based upon data taken with the telescope. The scientific impact of a paper can be measured quantitatively by the number of citations that the paper receives. In this poster, I examine the productivity and impact of the several 8-m class telescopes including Gemini, Keck, Magellan, Subaru, and the VLT telescopes using paper and citation counts. I also present results for a subset of 4-m telescopes and HST for comparison.

158

Education, Public Outreach, Citizen Science and Science Impact Poster Session *Exhibit Hall*

158.01

Asteroids Outreach Toolkit Development: Using Iterative Feedback In Informal Education Vivian White¹, M. Berendsen¹, S. Gurton¹, P. B. Dusenbery²

¹Astronomical Society of the Pacific, ²Space Science Institute's National Center for Interactive Learning. Exhibit Hall

The Night Sky Network is a collaboration of close to 350 astronomy clubs across the US that actively engage in public outreach within their communities. Since 2004, the Astronomical Society of the Pacific has been creating outreach ToolKits filled with carefully crafted sets of physical materials designed to help these volunteer clubs explain the wonders of the night sky to the public. The effectiveness of the ToolKit activities and demonstrations is the direct result of a thorough testing and vetting process. Find out how this iterative assessment process can help other programs create useful tools for both formal and informal educators.

The current Space Rocks Outreach ToolKit focuses on explaining asteroids, comets, and meteorites to the general public using quick, big-picture activities that get audiences involved. Eight previous ToolKits cover a wide range of topics from the Moon to black holes. In each case, amateur astronomers and the public helped direct the development the activities along the way through surveys, focus groups, and active field-testing. The resulting activities have been embraced by the larger informal learning community and are enthusiastically being delivered to millions of people across the US and around the world. Each ToolKit is delivered free of charge to active Night Sky Network astronomy clubs. All activity

write-ups are available free to download at the website listed here.

Amateur astronomers receive frequent questions from the public about Earth impacts, meteors, and comets so this set of activities will help them explain the dynamics of these phenomena to the public. The Space Rocks ToolKit resources complement the Great Balls of Fire museum exhibit produced by Space Science Institute's National Center for Interactive Learning and scheduled for release in 2011. NSF has funded this national traveling exhibition and outreach ToolKit under Grant DRL-0813528.

158.02

A Cluster Of Activities On Coma From The Hubble Space Telescope, StarDate, And McDonald Observatory

Mary Kay Hemenway¹, S. Jogee¹, K. Fricke¹, S. Preston¹

¹Univ. of Texas.

Exhibit Hall

With a goal of providing a vast audience of students, teachers, the general public, and Spanish-speakers with activities to learn about research on the Coma cluster of galaxies based on the HST ACS Treasury survey of Coma, McDonald Observatory used a many-faceted approach. Since this research offered an unprecedented legacy dataset, part of the challenge was to convey the importance of this project to a diverse audience. The methodology was to create different products for different (overlapping) audiences. Five radio programs were produced in English and Spanish for distribution on over 500 radio stations in the US and Mexico with a listening audience of over 2 million; in addition to the radio listeners, there were over 13,000 downloads of the English scripts and almost 6000 of the Spanish. Images were prepared for use in the StarDate Online Astronomy Picture of the Week, for ViewSpace (used in museums), and for the StarDate/Universo Teacher Guide. A high-school level activity on the StarDate/Universo Teacher Guide. A high-school level activity on the StarDate/Universo Teacher Guide. This guide has been distributed to over 1700 teachers nationally. A YouTube video about careers and research in astronomy using the Coma cluster as an example was produced. Just as the activities were varied, so were the evaluation methods.

This material is based upon work supported by the National Aeronautics and Space Administration under Grant/Contract/Agreement No. HST-EO-10861.35-A issued through the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS5-26555.

158.03

Starship Asterisk: APOD and General Astronomy Discussion Forum Robert J. Nemiroff $^{\!\!1}$

¹Michigan Technological Univ..

Exhibit Hall

A main discussion venue for the popular Astronomy Picture of the Day (APOD) website has been recently redesigned and upgraded. The online bulletin board is directly linked from the bottom of recent APODs served from http://apod.nasa.gov/. Formerly known as "The Asterisk," the site's new design is called "Starship Asterisk" and now declares its forums to be places on a starship, with the current APOD considered as appearing on the main view screen on the Bridge. A central "mission" of Starship Asterisk is to support APOD in various ways. Toward this end, the Bridge forum exists primarily for the (archived) discussion of that day's APOD, the Observation Deck forum facilitates APOD image submissions, and the Library creates a forum where no student question about astronomy is considered to be too easy or too hard. Additionally, Starship Asterisk now includes an astronomy news-oriented links forum titled the Communications Center, a citizen science-oriented links collection called the Science Labs, and classrooms including a free online, textbook-free Astro 101 course, taught by the author, complete with

video lectures and powerpoint slides. Typically, over 1,000 astronomy enthusiasts will browse Starship Asterisk on any given day. Although the vast majority of readers prefer to browse anonymously, the site has now garnered over 60,000 posts. A small but dedicated group of volunteer "officers" administer the bulletin board, answer questions about astronomy from curious APOD readers, and openly discuss various astronomy topics, frequently with intended humor. Perhaps surprisingly, the majority of volunteer officers tend NOT to be professional astronomers, but typically quite knowledgeable retirees exercising a lifelong interest in astronomy.

158.04

Amidst the Beauty of the Night Sky, Which of the Constellations am I? Kimberly A. Herrmann¹

¹Lowell Observatory. Exhibit Hall A well known constellation am I-I never set in the northern sky. Native Americans and Greeks, you see, Wrote legends when they recognized me. Two close stars still test for keen eyesight. Two point to the North Star - what a light! Look for my galaxies, you know where. I am ---- , the ----- ! (If you've an answer you'd care to try, Or check out more riddles, please stop by! Note: All my astronomy riddles are copyrighted.)

158.05

Dark Skies, Bright Kids: Year 2

Joleen K. Carlberg¹, K. Johnson¹, R. Lynch¹, L. Walker¹, R. Beaton¹, J. Corby¹, G. de Messieres¹, M. Drosback¹, N. Gugliucci¹, L. Jackson¹, A. Kingery¹, S. Layman², E. Murphy¹, W. Richardson¹, P. Ries¹, C. Romero¹, G. Sivakoff¹, K. Sokal¹, G. Trammell¹, D. Whelan¹, A. Yang¹, G. Zasowski¹ ¹University of Virginia, ²Charlottesville Astronomical Society. Exhibit Hall

The Dark Skies, Bright Kids (DSBK) outreach program brings astronomy education into local elementary schools in central Virginia's Southern Albemarle County through an after-school club. Taking advantage of the unusually dark night skies in the rural countryside, DSBK targets economically disadvantaged schools that tend to be underserved due to their rural locale. The goals of DSBK are to foster children's natural curiosity, demonstrate that science is a fun and creative process, challenge students' conceptions of what a scientist is and does, and teach some basic astronomy. Furthermore, DSBK works to assimilate families into students' education by holding family observing nights at the school. Now in its third semester, DSBK has successfully run programs at two schools with very diverse student populations. Working with these students has helped us to revise our activities and to create new ones. A by-product of our work has been the development of lesson plans, complete with learning goals and detailed instructions, that we make publically available on our website. This year we are expanding our repertoire with our new planetarium, which allows us to visualize topics in novel ways and supplements family observing on cloudy nights.

The DSBK volunteers have also created a bilingual astronomy artbook --- designed, written, and illustrated by UVa students --- that we will publish and distribute to elementary schools in Virginia. Our book debuted at the last AAS winter meeting, and since then it has been extensively revised and

updated with input from many individuals, including parents, professional educators, and a children's book author. Because the club is currently limited to serving a few elementary schools, this book will be part of our efforts to broaden our impact by bringing astronomy to schools we cannot go to ourselves and reaching out to Spanish-speaking communities at the same time.

158.06

The Hubble Education Program's Tactile Astronomy: Making the Universe Touchable

Bonnie Eisenhamer¹, M. Mutchler¹, K. Cordes¹, D. Weaver¹, H. Ryer¹

¹STScI.

Exhibit Hall

Tactile Astronomy supports the Hubble Education Program's efforts in bringing the wonders of the universe to everyone, regardless of their visual ability. This new section of the Amazing Space Website features "Images of the Month;" a collection of the latest Hubble images that can be printed in a tactile format. The images are specifically designed to be downloaded and printed on a thermal paper expansion machine, thus allowing the visually impaired to feel what they cannot see. In addition, there is a "special projects" section that currently features the limited-edition Tactile Carina Nebula booklet and accompanying materials, such as background text about the Carina Nebula and an audio tour. The opening of Tactile Astronomy is in celebration of Hubble's 20th anniversary and features the 20th anniversary image of a small portion of the Carina Nebula. New tactile images and additional projects will continue to be added to the site.

158.07

7 Minutes of Totality in 7 Years: Planning Ahead for August 2017 Jennifer L. Bartlett¹, S. Bell²

¹US Naval Observatory, ²HM Nautical Almanac Office, United Kingdom. Exhibit Hall

In rapid succession, two chances to experience a total solar eclipse will soon occur over the middle of the United States. Usually, a total solar eclipse is, at most, a once in a lifetime event. However, the celebrated shadows will race over the Shawnee National Forest, near Makanda, Illinois, twice in less than 7 years. The centerlines of the 2017 August 21 and 2024 April 08 eclipses will cross at this convenient location. If you are planning a trip to that legendary heart of darkness, you should consider a site just northwest of Makanda for both events.

The two eclipse centerlines are expected to intersect at 37° 38.2' N and 89° 15.4' W, in the Shawnee National Forest. In 2017, totality lasting about 2 min 45 sec is expected at this location, which is the maximum duration for that eclipse. In 2024, nearly 4 min 13 sec of darkness will occur at the crossover point, but the longest period of totality for this eclipse will be seen in Mexico.

Historically, southern Illinois is mostly sunny in late August and early April. If rain or clouds mar your 2017 experience, you can hope for better weather when you return in 2024. A number of activities can enrich your outreach program: spotting planets and stars, locating shadow effects, monitoring climate changes, and watching wildlife responses. In addition, you will be able to compare and contrast your observations during the two eclipses there. Planning an expedition to this rare intersection reduces your flexibility in case of inclement weather--a small price for the novelty of multiple visits.

Unless you are a dedicated eclipse chaser, 2017 may not seem imminent. However, your outreach program choices now may shape your plans for the eclipses to come.

For additional information, visit the USNO Eclipse Portal at

http://www.eclipse.org.uk/eclbin/query_usno.cgi

Public Outreach Efforts of the Canadian Astronomical Society

Dennis Crabtree¹, J. Rosvick², J. Bolduc-Duval³, J. Cami⁴, J. Di Francesco¹, Y. Dutil⁵, L. Edwards⁶, J. E. Hesser¹, N. Martimbeau⁷, P. Newbury⁸, G. Sarty⁹, I. Short¹⁰, H. Theijsmeijer¹¹

¹NRC-HIA, Canada, ²Thompson Rivers University, Canada, ³Cégep de Thetford Mines, Canada, ⁴University of Western Ontario, Canada, ⁵T3E, Canada, ⁶Caltech/IPAC, ⁷Montréal Planetarium, Canada, ⁸University of British Columbia, Canada, ⁹University of Saskatchewan, Canada, ¹⁰St. Marys University, Canada, ¹¹Manitoulin Secondary School, Canada.

Exhibit Hall

The Canadian Astronomical Society (CASCA) has a very active Education and Public Outreach (EPO) Committee that promotes and supports astronomy education and outreach across Canada. The Committee submitted a White Paper to Canada's Long Range Planning Panel in 2010 outlining the goals of Canadian astronomy EPO for the next 10 years. This poster will summarize the current activities of CASCA's EPO Committee and present the Committee's vision for the next decade of EPO in Canada.

158.09

More Than a Pretty Picture: Making WISE Data Accessible to the Public

Nancy Ali¹, B. Mendez¹, K. Fricke¹, E. L. Wright², P. R. Eisenhardt³, R. M. Cutri⁴, R. Hurt⁵, WISE Team ¹University of California Berkeley, ²UCLA, ³JPL, ⁴IPAC/Caltech, ⁵Caltech. Exhibit Hall

NASA's Wide-field Infrared Survey Explorer (WISE) has surveyed the sky in four bands of infrared light, creating a treasure trove of data. This data is of interest not only to the professional astronomical community, but also to educators, students and the general public. The Education and Public Outreach (E/PO) program for WISE is creating opportunities to make WISE data accessible to these audiences through the Internet as well as through teacher professional development programs. Shortly after WISE took its first light image in January 2010, images have been featured weekly on the WISE website. These images serve to engage the general public through "pretty pictures" that are accompanied by educational captions. Social media such as Facebook and Twitter are used to further engage the public with the images. For a more comprehensive view of WISE images, we are creating a guided tour of the infrared sky on the WorldWide Telescope. The public will be able to use the free WorldWide Telescope software to interact with WISE images and listen to narration that describes features of the Universe as seen in infrared light. We are also developing resources for teachers and students to access WISE data when in becomes public in 2011 to learn about astronomical imaging and to conduct authentic scientific investigations.

158.10

GLOBE At Night: Mobilizing The Citizen-scientist

Constance E. Walker¹, M. Newhouse¹

¹National Optical Astronomy Observatory.

Exhibit Hall

GLOBE at Night is an annual international citizen-science event encouraging everyone to measure local levels of light pollution in February and March and contribute their observations online to a world map. (See www.globeatnight.org.) The campaign is hosted by the National Optical Astronomy Observatory (NOAO) in partnership with ESRI. In the last three years citizen-scientists from around the world contributed more than 50,000 observations, with nearly 18,000 data points from the 2010 campaign. During the same time, millions of touch-based, GPS-enabled smartphones and tablets have been sold worldwide.

Each year NOAO staff has to discard data points due to inaccurate reporting of the location (latitude and

longitude). Despite the use of innovative mapping tools on the data reporting web page, it is too easy to mistype numbers or forget a negative sign, spuriously relocating data points. Additionally, there is a time lag between when the data is collected at night and when it is reported later that can allow for additional error.

One approach to address these problems would be to create a way to submit the data when it is observed and have a more automated GPS capability for reporting an accurate location. The rise in popularity of GPS-enabled mobile devices provides such a solution. These phones include state-of-the-art browsers that have access to the GPS and other data (date, time). These devices can potentially be used to show an appropriate magnitude/sky chart to the citizen-scientist and submit the data in real time, as the observation is made.

NOAO staff is building a web application for mobile devices that will help realize these possibilities and potentially enable the accurate reporting of many more observations this year. Our poster will discuss this effort and describe what we hope to accomplish.

158.11

Citizen Sky, An Update on the AAVSO's New Citizen Science Project

Rebecca Turner¹, A. Price¹, A. Henden¹, R. Stencel², B. Kloppenborg² ¹AAVSO, ²University of Denver.

Exhibit Hall

Citizen Sky is a multi-year, NSF-funded, citizen science project focusing on the bright variable star, epsilon Aurigae. Citizen Sky goes beyond simple observing to include a major data analysis component. The goal is to introduce the participant to the full scientific process from background research to paper writing for a peer-reviewed journal. The first year of the project, 2009-10, was dedicated to developing project infrastructure, educating participants about epsilon Aurigae, and training these participants to observe the star and report their data. Looking forward, years two and three of the project will focus on assembling teams of participants to work on their own analysis and research. Results will be published in a special issue of the peer-reviewed Journal of the AAVSO. This project has been made possible by the National Science Foundation.

158.12

Development of DSLR Photometry as an Example of a Citizen Sky Team

Brian K. Kloppenborg¹, R. E. Stencel¹, A. Price², R. Turner², A. Henden² ¹University of Denver, ²AAVSO.

Exhibit Hall

One of the primary goals of the Citizen Sky project is to foster the development of Teams of every-day people with an interest in astronomy. These groups are composed of people with different, yet complementary skill sets who work together towards a common goal. Each team has a team leader and a professional astronomer assigned to act as an advisor. Here we highlight the work of one particular team who has produced documentation and software to teach first-time observers how to use consumer-grade digital cameras to produce accurate photometric magnitudes. We present a short history, the completed products, and lessons learned from this team.

We acknowledge support from the NSF Informal Science Education Division, to the AAVSO and the University of Denver.

Facebooking Citizen Science with the Zooniverse

Joseph Moore¹, P. L. Gay², K. Hogan², C. Lintott³, C. Impey⁴, C. Watson⁵

¹Southern Illinois University Edwardsville, ²Southern Illinois University Edwardsville / Astronomy Cast, ³Adler Planetarium / Oxford University, ⁴University of Arizona, ⁵freelance. Exhibit Hall

While fully online citizen science projects like Galaxy Zoo and Moon Zoo are able to garner participation by tens to hundreds of thousands of people, this success pales next to the number of people who use Facebook. With a population well over half a billion, Facebook is, at the time of this writing, the largest single online community. As an experiment in social science-engagement, we have created Facebook fan pages for Zooniverse science tasks, social-sharing apps for Moon Zoo and Galaxy Zoo, and a novel galaxy-related citizen science project all within Facebook. In this poster we present early analysis on how these engagements attract both old and new users, and how users choose to share and interact through these pages.

158.14

Motivation of Citizen Scientists Participating in Moon Zoo

Shanique Brown¹, P. L. Gay¹, C. S. Daus¹

¹Southern Illinois University Edwardsville.

Exhibit Hall

Moon Zoo is an online citizen science project with the aim of providing detailed crater counts for as much of the Moon's surface as possible. In addition to focusing on craters, volunteers are encouraged to remain vigilant for sightings of atypical features which may lead to new discoveries. Volunteers accomplish these tasks by exploring images captured by NASA's Lunar Reconnaissance Orbiter (LRO) which has a resolution of 50cm per pixel. To be successful, Moon Zoo needs to attract and retain a large population of citizen scientists. In this study, we examine the factors motivating Moon Zoo participants who invest many hours exploring these images.

In this, the first of a two-phased study, we conducted a qualitative analysis using semi-structured interviews as a means of data collection. A stratified sample of participants was used in an attempt to uncover the driving forces behind decisions to participate from a wide-range of participants. Inquiring and probing questions were asked about factors which led volunteers to Moon Zoo as well as reasons which kept them committed to exploring the Moon's surface through this online portal. Responses were then categorized using a grounded theory approach, and frequency distributions are calculated where appropriate.

Aggregate results from these interviews are presented here including the demographics of the sample and motivators as per the content analysis. The information gathered from this phase will be used to guide the development of an online survey to further explore volunteers' motivation based on the presented classification schemes. The survey will then be used to guide future research and development in the area of citizen science in the field of astronomy. These findings will also be useful in charting new boundaries for future research.

158.15

Stars Above, Earth Below: Astronomy in the National Parks Tyler E. Nordgren¹ ¹Univ. of Redlands. Exhibit Hall

The U.S. national parks that protect our enjoyment of the landscape around us by day, also protect our enjoyment of the sky above at night. With the growth of light pollution, the view of the stars and Milky Way overhead has become as rare as the views of glaciers, geysers, and grizzlies that bring millions of visitors to the parks every year. Through the pristine view of a starry sky at night park visitors are primed to learn about our planet, its place in the solar system, and the larger Universe in which we live. The national parks are therefore the largest informal educational setting for reaching millions of people from all over the world who might not otherwise encounter astronomical outreach. The material in this presentation has been field tested in national parks, campgrounds, lodges, and visitor centers over the last four years and is elaborated on in the just released book: "Stars Above, Earth Below: A Guide to Astronomy in the National Parks." Funding for this project was provided by The Planetary Society.

Monday, January 10, 2011, 10:00 AM - 11:30 AM

102

Results from the First Year of Observations with the Cosmic Origins Spectrograph Special Session *Ballroom 6C*

102.01

Quasar Absorption Lines in the Extreme Ultraviolet: The Smoking Guns of Cosmic Feedback Todd Tripp 1

¹University of Massachusetts. 10:00 AM - 10:15 AM Ballroom 6C

Three years ago at the winter AAS meeting I presented a talk entitled, perhaps somewhat pretentiously, "Terra Incognita: Probing The IGM-Galaxy Interface With COS." Now that the Cosmic Origins Spectrograph (COS) has been successfully installed on the Hubble Space Telescope, this instrument is delivering data that even exceed my hopes and predictions from three years ago. This talk will demonstrate that COS is enabling investigations of aspects of the Universe that have never been seen before. Specific examples will include the following: (1) Detections of absorption lines of Ne VIII and Mg X, which probe highly-ionized and low-density plasmas that can exist at temperatures in excess of 10⁶ K. Due to the low density of galaxy halos and the IGM, X-ray emission from these plasmas is entirely undetectable with current or future missions. (2) Detections of remarkably strong O VI absorbers spanning velocity ranges in excess of hundreds of km/s, probably arising in galactic winds. While such outflows can be seen from the ground, the extreme ultraviolet provides a much richer suite of physical conditions diagnostics. (3) Detection of molecular hydrogen in unexpected places. An unifying thems of these examples is cosmic feedback and accretion -- these observations provide important new constraints on how galaxies interact with their surroundings.

102.02

The DAO of Tau: Disks, Accretion, and Outflows in an FUV Survey of T Tauri Stars Gregory J. ${\rm Herczeg}^1$

¹*Max-Planck-Institut, Germany.* 10:15 AM - 10:30 AM

Ballroom 6C

Classical T Tauri stars offer a unique window into star+disk systems that are still in the accretion/outflow phase yet are no longer surrounded by an opaque circumstellar envelope. These objects hold the key to understanding how magnetospheric accretion occurs, how accretion powers outflows, and what the physical and chemical conditions are in the disks where planet formation occurs. Far-ultraviolet spectra of classical T Tauri stars provide powerful and unique diagnostics of each of these processes. In the ongoing Disks, Accretion, and Outflows of T Tau stars (DAO of Tau) program, we are using HST/COS and STIS to survey these diagnostics in high-resolution FUV spectra of 26 CTTSs and 6 WTTSs. Our first results

include identifying new emission line diagnostics of the disk surface, detecting weak accretion in profiles of hot lines from a WTTS with a disk, finding warm winds from only some objects, and catching an amazing flare on a WTTS.

102.03

Observational and Theoretical Studies of the Intergalactic Medium

J. Michael Shull¹

¹Univ. of Colorado. 10:30 AM - 10:45 AM Ballroom 6C

The Cosmic Origins Spectrograph (COS) installed on the Hubble Space Telescope provides access to highquality ultraviolet spectra of the intergalactic medium (IGM) and galactic halos. I will report on new COS results on the physical state, baryon content, and spatial distribution of the the IGM at redshifts z &It; 0.5. COS has also recently measured the epoch of reionization in helium (He II) toward HE2347-4342 at redshifts z &It; 2.9. This talk will also describe the Colorado group's numerical simulations of the IGM and dynamical and radiative feedback from galaxy formation, using the adaptive-mesh N-body hydrodynamic code Enzo. These simulations help us understand the effects of IGM shock-heating, metal-transport, radiative cooling, and photoionization of the complex structures in the "Cosmic Web" of matter.

102.04

Mysteries of the North Star: Far Ultraviolet HST/COS Spectroscopy of the Classical Cepheid Polaris Edward F. Guinan¹

¹Villanova Univ.. 10:45 AM - 11:00 AM

Ballroom 6C

Polaris (α UMi; F7Ib-II) is the best known star in the northern sky. It has enjoyed special standing since the Earth's precession brought our north celestial pole to its almost exact direction. Polaris is also the nearest (~130 pc) and brightest (V ~ 1.97-mag) classical Cepheid. Polaris has proven to be full of surprises, displaying both a systematic decrease in light amplitude, an increase in pulsation period and a probable increase in luminosity. Presently Polaris has a light amplitude ΔV^{\sim} 0.045-mag, its 3.97-day period is increasing at +3.5sec/year and its mean brightness has apparently increased by ~0.2-mag over the past century (Engle & Guinan 2006). Recent FUSE observations show the presence of CIII 977/1176A and OVI 1032/1038A emissions, indicative of hot ~30,000-300,000 K plasmas (Engle & Guinan, 2007). A study of IUE data indicates a possible small temperature increase (which in the FUV-region is very sensitive to Teff) between 1978/79 and 1991/93, indicating an increase of ~35+/-12K. Also, Polaris, along with two other Cepheids beta Dor and delta Cep, have been detected as soft-X-ray sources with $\log L_x \simeq 29.0 \text{ ergs/sec.}$ But Polaris has a nearby binary companion that could contribute to the observed X-ray emission. HST/COS medium-resolution ~1150-2000Å spectrometry was conducted during Dec-2009. These observations were conducted to investigate possible evolutionary changes (manifested by small changes in Teff) and also to study upper atmospheric high energy emissions. Below ~1400A data is essentially free of the stellar continuum of the F8-supergiant and contains important diagnostic high energy emission lines such as C III, Ly-alpha, NV, OI, CII, & Si IV. At wavelengths >1600A, the stellar photospheric flux rapidly increases. We report on analyses of the COS observations and discuss implications for Cepheid evolution and upper atmosphere heating mechanisms. This work is supported by NASA Grant-HST-GO-11726.

102.05 Size and Kinetic Luminosity of Low Redshift Quasar Outflows Nahum Arav^1

¹Virginia Tech. 11:00 AM - 11:15 AM

Ballroom 6C

Over the past several months the new UV spectrograph aboard HST is giving us high quality data of AGN outflows, aka warm absorbers to the X-ray community. I will describe very new results from our program that aim at finding the size, kinetic luminosity and chemical abundances of these outflows. We acknowledge support from NASA through HST program (11686), and from NSF grant AST 0837880.

103 *Kepler I* Oral Session *Ballroom 6B*

103.01

Confirming The Planetary Nature Of Kepler Transit Candidates Orbiting Pulsating Stars With Light Travel Time Measurements

Jessie Christiansen¹, J. F. Rowe¹, F. Mullally¹, Kepler Science Team

¹NASA Ames Research Center/SETI Institute.

10:00 AM - 10:10 AM

Ballroom 6B

The first extrasolar planets were found orbiting pulsars, and were detected via the changes in the arrival time of the pulses caused by the gravitational effect of the planets on the pulsar. Planets orbiting pulsating stars, such as delta Scuti/gamma Doradus stars, will distort the arrival times of maximum light in the light curves of these stars in the same fashion. We investigate the possibility of detecting this phenomenon in Kepler light curves, and constrain the mass limits that could be set on transiting companions. This method would provide an independent test of the planetary nature of Kepler transiting candidates. Kepler was selected as the 10th mission of the Discovery Program. Funding for this mission is provided by NASA, Science Mission Directorate.

103.02

A Bayesian Approach to Systematic Error Correction in Kepler Photometric Time Series Jon Michael Jenkins¹, J. VanCleve¹, J. D. Twicken¹, J. C. Smith¹, Kepler Science Team ¹SETI Institute. 10:10 AM - 10:20 AM Ballroom 6B In order for the Kepler mission to achieve its required 20 ppm photometric precision for 6.5 hr observations of 12th magnitude stars, the Presearch Data Conditioning (PDC) software component of the Kepler Science Processing Pipeline must reduce systematic errors in flux time series to the limit of stochastic noise for errors with time-scales less than three days, without smoothing or over-fitting away the transits that Kepler seeks. The current version of PDC co-trends against ancillary engineering data and Pipeline generated data using essentially a least squares (LS) approach. This approach is successful for quiet stars when all sources of systematic error have been identified. If the stars are intrinsically variable or some sources of systematic error are unknown, LS will nonetheless attempt to explain all of a given time series, not just the part the model can explain well. Negative consequences can include loss of astrophysically interesting signal, and injection of high-frequency noise into the result. As a remedy,

we present a Bayesian Maximum A Posteriori (MAP) approach, in which a subset of intrinsically quiet

and highly-correlated stars is used to establish the probability density function (PDF) of robust fit parameters in a diagonalized basis. The PDFs then determine a "reasonable" range for the fit parameters for all stars, and brake the runaway fitting that can distort signals and inject noise. We present a closed-form solution for Gaussian PDFs, and show examples using publically available Quarter 1 Kepler data. A companion poster (Van Cleve et al.) shows applications and discusses current work in more detail.

Kepler was selected as the 10th mission of the Discovery Program. Funding for this mission is provided by NASA, Science Mission Directorate.

103.03

Validating Kepler Planet Candidates

Jack J. Lissauer¹, G. Torres², G. Marcy³, T. Brown⁴, R. Gilliland⁵, T. N. Gautier⁶, H. Isaacson³, A. Dupree², Kepler Science Team

¹NASA Ames Research Center, ²Center for Astrophysics, ³University of California, ⁴LCOGT, ⁵STScI, ⁶JPL. 10:20 AM - 10:30 AM

Ballroom 6B

The Kepler Science Team has identified more than 700 transit-like signatures in the first 43 days of data returned from the spacecraft (Borucki et al. 2010, arXiv1006.2799B). However, only 7 of these candidates have been confirmed as planets as of late September 2010. The number of true planets in this sample is clearly far larger than 7, but the sample is also 'contaminated' with false-positives, including many from eclipsing binary stars. Separating the wheat from the chaff requires a careful study of individual candidates using both Kepler photometry and spectroscopic and imaging data from the ground. Techniques that the Science Team is developing to address these issues, which include detailed analysis of the photometric data and follow-up observations with ground-based telescopes, will be presented. Kepler was selected as the 10th mission of the Discovery Program. Funding for this mission is provided by NASA, Science Mission Directorate.

103.04

Kepler Discovery Of An A-star With A Hot-planetary Companion.

Jason Rowe¹, W. J. Borucki¹, S. B. Howell², R. L. Gilliland³, L. A. Buchhave⁴, N. M. Batalha⁵, D. W. Latham⁶, Kepler Science Team

¹NASA Ames Research Center, ²National Optical Astronomy Observatory, ³Space Telescope Science Institute, ⁴Niels Bohr Institute, Copenhagen University, Denmark, ⁵San Jose State University, ⁶Harvard-Smithsonian Center for Astrophysics.

10:30 AM - 10:40 AM

Ballroom 6B

We present Kepler photometry of a bright (Kepmag=10) closely separated (1") A-star stellar binary. Time series photometry of the system reveals a transiting Jupiter-sized companion in a 1.76 d orbit. Detailed modeling of the phased light curve in conjunction with high-resolution speckle imaging allow us to identify the true host of the transiting companion and to account for third light contamination. The high-duty cycle and precision of Kepler photomety enables us to observe phase-changes of the planet as well as Doppler boosting and ellipsoidal distortions of the host star. With these observations we measure the mass, radius, temperature and orbital solution of the companion and confirm its planetary nature. Kepler was selected as the 10th mission of the Discovery Program. Funding for this mission is provided by NASA, Science Mission Directorate.

The Architectures of Planetary Systems from Transit Observations

Eric B. Ford¹, D. C. Fabrycky², M. J. Holman³, J. J. Lissauer⁴, A. V. Moorhead¹, R. C. Morehead¹, D. Ragozzine³, J. H. Steffen⁵, D. Koch⁴, Kepler Science Team

¹Univ. of Florida, ²UC Santa Cruz, ³CfA, ⁴NASA Ames, ⁵Fermilab.

10:40 AM - 10:50 AM

Ballroom 6B

The architectures of multiple planet systems can provide valuable constraints on models of planet formation, including the extent and cause of orbital migration, eccentricity excitation and inclination excitation. NASA's Kepler mission has discovered a planetary system with multiple transiting planets (Holman et al. 2010) and several stars with multiple transiting planet candidates (Steffen et al. 2010). For each planet, transit photometry can measure the orbital period, orbital phase, transit duration, planet size (relative to the host star), and, in favorable cases, the orbital inclination. For systems with multiple transiting planets, one can begin to piece together the architecture of the planetary system, including key features such as the proximity to mean motion resonance, potential for significant secular interactions, and the likely relative inclinations. The set of potential architectures can often be further narrowed by incorporating the constraint of long-term orbital stability (for plausible mass-radius relations) and/or incorporating complimentary observations (e.g., radial velocities, Rossiter-McLaughlin effect, transit timing, out-of-transit light curve). We describe the methodology for characterizing the architecture transiting planet systems and present early results of such analyses for the Kepler-9 system, as well as candidate multiple planet systems previously identified by Kepler. Funding for Kepler is provided by NASA's Science Mission Directorate and for this research by the *Kepler* Participating Scientist Program.

103.06

The Distribution of Orbital Eccentricities for Kepler Planet Candidates

Althea Moorhead¹, E. B. Ford¹, R. Morehead¹, Kepler Science Team

¹University of Florida. 10:50 AM - 11:00 AM

Ballroom 6B

The population of exoplanets detected with the radial velocity method has revealed that Jupiter-size planets possess a large range in orbital eccentricity, with a characteristic eccentricity of about 0.3. This discovery has revolutionized our theories of planet formation. With the additional discovery of hundreds of exoplanet candidates by the Kepler mission, we can probe the eccentricity distribution of smaller exoplanets. Due to a near degeneracy between the eccentricity, direction of pericenter and impact parameter, transit photometry alone will not measure the orbital eccentricity for most planets discovered by Kepler. In some cases, it will be possible to measure eccentricities of individual planets thanks to complementary observations (e.g., radial velocities, transit timing variations, occultation photometry, NIR transit photometry). Even in the absence of individual eccentricities, it is possible to study the distribution of eccentricities based on the distribution of transit durations (relative to the maximum transit duration for a circular orbit). We present an early analysis of the duration distribution for planet candidates identified by the Kepler mission and discuss the implications for the eccentricity distribution. We compare results for giant and smaller planet candidates. Additionally, we identify planet candidates whose transit durations exceed the maximum transit duration for a circular orbit (which depends on the density of the host star). We consider the possibility of inaccurate stellar densities and the implications of the long-duration transit candidates for the exoplanet eccentricity distribution and its dependence on planet size.

KOI-54: The Remarkable Pulsating, Periastron-Pumped Binary Star

William F. Welsh¹, J. A. Orosz¹, R. L. Gilliland², C. Aerts³, T. M. Brown⁴, E. Brugamyer⁵, W. D. Cochran⁵, J. A. Guzik⁶, D. W. Kurtz⁷, D. W. Latham⁸, G. W. Marcy⁹, S. A. Quinn⁸, W. Zima³, D. G. Koch¹⁰, W. J. Borucki¹⁰, Kepler Science Team

¹San Diego State University, ²STScI, ³Instituut voor Sterrenkunde, KU Leuven, Belgium, ⁴LCOGT, ⁵Univ. of Texas, ⁶LANL, ⁷Univ. Central Lancashire, United Kingdom, ⁸CfA, ⁹UC Berkeley, ¹⁰NASA Ames. 11:00 AM - 11:10 AM

11.00 AIVI - 11.10 F

Ballroom 6B

A previously-known unremarkable A star has been discovered by Kepler to be a fascinating object: KOI-54 exhibits sharp brightening events every 42 days and a beat-pattern of pulsations locked in phase with the brightenings. We have determined that this is a highly eccentric face-on binary star system and the brightenings are due to tidal distortion plus mutual irradiation of the stars at periastron passage. The periodic driving produces a rich set of tidally-induced g-mode pulsations locked to the orbital period. We present spectral analysis, radial velocities, the exquisite Kepler photometry of KOI-54, and a model that successfully reproduces these observations.

Kepler was selected as the 10th mission of the Discovery Program. Funding for this mission is provided by NASA, Science Mission Directorate.

103.08

The High Albedo of the Hot-Jupiter Kepler-7b

Brice-Olivier Demory¹, S. Seager¹, H. Kjeldsen², Kepler Science Team

¹Massachusetts Institute of Technology, ²Department of Physics and Astronomy Aarhus University, Denmark.

11:10 AM - 11:20 AM

Ballroom 6B

Kepler-7b is the least dense extrasolar planet discovered to date. This 4.9-day period hot-Jupiter has a mass of half of Jupiter (0.47 M_J) but a radius 50% larger (1.48 R_J). We present a global analysis of this system including more than 180 high-precision transits and occultations obtained with NASA's Kepler mission. Our best fit to the observations yields a high geometric albedo, with a minor part due to the planetary thermal emission. Therefore most of the planet light observed by Kepler is scattered light, suggesting the presence of a highly reflective layer in its upper atmosphere. We discuss the nature of this layer, possibly made of silicate condensates forming high-altitude clouds decks.

Kepler was selected as the 10th mission of the Discovery Program. Funding for this mission is provided by NASA, Science Mission Directorate.

103.09

Validation And Characterization Of Kepler Exoplanet Candidates With Warm Spitzer

Jean-Michel Desert¹, Kepler Science Team

¹*Harvard University.*

11:20 AM - 11:30 AM

Ballroom 6B

I present the status and results from an ongoing project to use 800 hours of the Spitzer SpaceTelescope to gather near-infrared photometric measurements of transiting extrasolar planet candidates detected by the Kepler Mission.

By combining occultation measurements of the reflected starlight in the optical with estimates of the thermal emission in the near-infrared, we are able to constrain the energy budget of these planets and compare such constraints to those for the Solar system giant planets.

By comparing the light curves spanning times of primary transit for candidates observed with Kepler and Spitzer, we can exclude significant sources of astrophysical false positives resulting from blends (e.g. background eclipsing binaries) that mimic an exoplanetary signature in the Kepler bandpass. I show how our infrared observations can help to validate the planetary nature of several candidates with small radii, which could be rocky in composition.

104

HEAD: High Energy Processes in Star Formation Special Session *Ballroom 6A*

104.01

X-Ray Spectroscopy of Accretion Shocks in Young Stars Nancy S. Brickhouse¹ ¹Harvard-Smithsonian, CfA. 10:00 AM - 10:15 AM

Ballroom 6A

High resolution X-ray spectroscopy of accreting young stars is providing new insights into the physical conditions of the shocked plasma. While young stars exhibit exceedingly active coronae (>10 MK) with highly energetic flares, the relatively low temperature (~3 MK), high density (>10¹² cm⁻³) accretion shock can only be clearly distinguished at high spectral resolution. The nearby Classical T Tauri star TW Hydrae was the first to show evidence of accretion using 50 ks with the Chandra High Energy Transmission Grating (HETG). More recently a Chandra HETG Large Program

(489 ks obtained over the course of one month) on TW Hydrae has found evidence for a new type of coronal structure. In the standard model, the accreting gas shocks near the atmosphere of the star and gently settles onto the surface as it slows down and cools. On TW Hydrae the observed post-shock region is not this predicted settling flow, since its mass is 30 times the mass of material that passes through the shock. Instead the stellar atmosphere must be heated to soft X-ray emitting temperatures. Of the CTTS systems observed with the gratings on Chandra and XMM-Newton not all show the accretion shock signature; however, all of them show excess soft X-ray emission related to accretion. The production of highly charged ions in the proximity of both open and closed magnetic field lines has important implications for coronal heating, winds and jets in the presence of accretion. This work is supported by the Chandra X-ray Observatory through a NASA contract with the Smithsonian Astrophysical Observatory.

104.02

X-ray Irradiation of Protoplanetary Accretion Disks Alfred E. Glassgold¹

¹*UC, Berkeley.* 10:15 AM - 10:30 AM *Ballroom 6A*

Young stellar objects radiate large numbers of keV-photons that are able to penetrate significant columns of gas and thus ionize and heat circumstellar material, including the accretion disks and outflows of very young stars. The unshielded ionization rates are high. At a distance of 1 AU from a young stellar object with a moderately strong X-ray source, they can be 100 million times the standard ionization rate associated with galactic cosmic rays. X-ray irradiation of a typical T Tauri star disk generates a layered atmosphere, ranging from a thin H II region through hot and warm regions on top of the main accretion disk. In the transition from warm to cool, the gas changes from atomic to molecular. This transition region produces a rich set of emission lines from the ultraviolet through the infrared. A

good diagnostic of the effects of X-rays from young stellar objects is the Ne II fine structure line at 12.8 microns. This line has now been detected in more than fifty young stellar objects by *Spitzer* and ground-based telescopes. Since X-rays from young stellar objects penetrate disks down to vertical column densities of order 10 g per square cm, they help determine the location of the active accretion layer of disks governed by the magneto-centrifugal instability. In addition to directly probing the disk, stellar X-rays affect the stellar and disk winds of young stellar objects, including photo-evaporative flows, and thereby influence the dispersal of circumstellar disks.

104.03

X-rays from Young Massive Stars David H. Cohen¹

¹Swarthmore College. 10:30 AM - 10:45 AM Ballroom 6A

O stars are powerful sources of X-ray emission and are often the strongest X-ray sources in young clusters and SFRs. Massive stars are not magnetically active, even in the minority of cases where they have detectable magnetic fields. Rather, their X-ray emission is caused by one (or more) of three mechanisms: embedded wind shocks in all O stars, colliding wind shocks in close binaries, and magnetically channeled wind shocks in massive stars with strong dipole magnetic fields. I will discuss these mechanisms and their manifestations in three specific examples: the O2 supergiant HD 93129A in Trumpler 14, Kleinman's Anonymous Star in M17, and theta1 Ori C in the Orion Nebula Cluster.

104.04

Numerical Simulations of Accretion and Outflows in Young Stars

Marina M. Romanova¹ ¹Cornell University. 10:45 AM - 11:00 AM Ballroom 6A

I will discuss results of 2D and 3D MHD simulations of disk accretion onto young rotating magnetized stars. The disk magnetosphere interaction leads to formation of funnel streams and hot spots on the stellar surface. The energy distribution in the spots is such that the highest energy photons are expected to radiate from the central parts of spots. The oscillation of the shock wave is expected but it can be smeared by the inhomogeneity in the shock front. If the disk carries the magnetic field, then the disk magnetosphere interaction leads to reconnection events and possibly to the X-ray flares. MRI simulations show different flaring behavior in cases of the parallel and anti-parallel fields. Non-stationary accretion can lead to the conical shaped winds similar to X-winds from the disk-magnetosphere boundary, where 10-30 percent of matter is accelerated by the magnetic force up to and beyond the escape speed. A smaller part of matter is accelerated up to much higher velocities in the axial region along stellar field lines. Research is supported by NASA and NSF grants.

104.05

The High-Energy Environment of Young Stars Manuel Guedel¹

¹University of Vienna, Austria. 11:00 AM - 11:15 AM Ballroom 6A

The environment of young stars is shaped by a complex interplay between stellar radiation, circumstellar material such as disks or envelopes, mass accretion flows onto the star, mass outflows from the star or the stellar disk, and jets accelerated near the star. High-energy radiation and particles

are especially important in ionizing and heating the circumstellar gas and to drive chemical networks. Radio and soft X-ray radiation provide the best evidence for high-energy processes in young stars, and relevant observations suggest that much of the high-energy output is the consequence of frequent flaring. This concept predicts high-energy output not yet accessible to observations, such as non-thermal hard X-ray radiation beyond 10 keV, frequent coronal mass ejections, and high-energy particles in the stellar winds. On larger scales, outflows and jets produce high-energy radiation as well, although the heating mechanism is not entirely clear. Jet X-rays add to the circumstellar radiation field On the largest scales, one finds extended plasma bubbles in star-forming regions that contribute further X-ray emission to the stellar environment. I will discuss the above issues and present new observations that suggest an important role for high-energy processes in young stellar environments.

104.06

Fast Magnetic Reconnection and Acceleration of Energetic Particles Alex Lazarian¹ ¹Univ. of Wisconsin. 11:15 AM - 11:30 AM

Ballroom 6A

Magnetic reconnection is a process that changes magnetic field topology and releases magnetic energy. In most astrophysical environments, including most of the ISM, the electric conductivity is high and the transforming of magnetic energy into Ohmic heating during reconnection is negligible. This opens interesting possibilities of transforming a substantial part of the magnetic energy into the energy of cosmic rays, provided that there exist a process of fast magnetic reconnection. A model of magnetic reconnection proposed in Lazarian & amp; Vishniac (1999) is appealing as it predicts that the only requirement for the fast reconnection is the presence of turbulence. The latter is ubiquitous in astrophysical environments. The model has been successfully tested numerically recently and I shall discuss its implications for particle acceleration. I shall show evidence of the existence of both the first and second order Fermi acceleration processes in the numerical simulations that make use of the reconnection set ups in weakly turbulent environments. The recent data obtained with Voyagers and with MILAGRO data is suggestive that magnetic reconnection does accelerate energetic particles. This opens a new avenue for the cosmic ray acceleration research.

105

Binary Stellar Systems, X-ray Binaries Oral Session *Room 615/617*

105.01D Optical Studies of γ-Ray Binaries Christina Aragona¹

¹Lehigh University. 10:00 AM - 10:20 AM Room 615/617

Recently, the launch of the Fermi Gamma-Ray Observatory has led to the discovery of many new γ-ray sources, including γ-ray binaries. These systems are high mass X-ray binaries which exhibit an unusual feature of very high energy MeV-TeV emission. Six high mass X-ray binaries have been observed which fulfill these criteria: LS 5039, LS I +61 303, PSR B1259--63, Cyg X-1, Cyg X-3, and HESS J0632+057. LS 5039, LS I +61 303, and Cyg X-3 have all been detected by Fermi and are included in the Fermi LAT one-year Point Source Catalog. Analysis of the high energy emission for these sources relies partly on optical studies which reveal details about the orbital parameters, the mass donor star, and the stellar wind.

Here, I will present results from optical spectra of LS 5039 and HD 259440, the proposed optical counterpart of HESS J0632+057. I have used spectra of the H alpha line obtained with the Southern Astrophysical Research (SOAR) Telescope to examine the stellar wind of LS 5039. The possible binarity of HD 259440 has not been confirmed although X-ray and gamma-ray properties of the system are consistent with other known gamma-ray binaries. Using optical spectra of this system, I have determined the physical properties of the massive star and placed constraints on the orbital parameters. I am grateful for support from NASA DPR Nos. NNX08AV70G, NNX09AT67G, NNG08E1671, and an institutional grant from Lehigh University.

105.02D

Fundamental Properties of Accreting Compact Objects Jennifer L. ${\rm Blum}^1$

¹University of Michigan.

10:20 AM - 10:40 AM

Room 615/617

Galactic accreting compact objects, such as stellar-mass black holes and neutron stars can give us a unique perspective into the behavior of matter in extreme conditions. However, the exact nature of accretion onto these objects is not yet well understood. X-ray studies provide us with a means to observe the innermost regions around these objects and to test our theories of general relativistic physics. Through X-ray analyses we can constrain the physical parameters necessary to make logical deductions regarding compact object properties, such as disk winds, relativistic jets, the Kerr metric, and the neutron star equation of state.

Here we present spectral modeling results from three accreting X-ray binaries. Specifically, we analyze Suzaku spectra from two stellar-mass black hole X-ray binaries, GRS 1915+105 and H1743-322, and one neutron star X-ray binary, 4U 1636-53. For GRS 1915+105 and 4U 1636-53, we use the relativistic iron line, which is part of a reflection spectrum, as a diagnostic for measuring black hole spin and neutron star radius, respectively. We find that while we can exclude a spin of zero at the 2 sigma level of confidence for GRS 1915+105, data selection and disk reflection modeling nuances can be important when estimating the spin value. For 4U 1636-53, we provide upper limits on the neutron star radius by estimating the radial extent of the inner accretion disk, which are important for constraining models for the neutron star equation of state. Moreover, when testing for the presence of disk winds in H1743-322 (which are key to understanding the nature of accretion disk outflow), we do not detect Fe XXV or Fe XXVI absorption lines in its spectra of H1743-322; implying that disk winds may be state dependent.

105.03

Planetary Nebulae, Blue Stragglers and Binary Mergers

Orsola De Marco¹, G. H. Jacoby², J. Davies³, H. E. Bond⁴, P. Harrington⁵ ¹Macquarie University, Australia, ²Carnagie Observatories & GMT, ³Caltech, ⁴Space Telescope Science Institute, ⁵University of Maryland.

10:40 AM - 10:50 AM

Room 615/617

The plot has thickened over the origin of planetary nebulae (PN) and the role played by binary interactions. One of the outstanding questions is why the brightest PN in every galaxy is limited to the same maximum brightness (making the ensemble of PN a standard candle): in older galaxies PN should be less luminous than in younger galaxies because their central stars have lower mass and luminosity. It has been proposed that the bright end of the PN luminosity function is populated by PN descending from blue stragglers, stars that have a binary or even merger origin, making over-massive and over-luminous PN in old populations. Without blue stragglers, PN should be absent in the oldest populations

such as globular clusters. There are, however, 4 PN known in the Galactic globular cluster system. We present here HST observations of two of them, JaFu1 (in Pal 6) and IRAS18333-2357 (in M22) that reveal characteristics (e.g., central star mass, nebular morphology) that support the binary origin hypothesis.

105.04

Angular Momentum Transport during Direct Impact Mass Transfer

Jeremy F. Sepinsky¹, B. Willems², V. Kalogera²

¹University of Scranton, ²Northwestern University.

10:50 AM - 11:00 AM

Room 615/617

We investigate the transfer of angular momentum between the components of an interacting binary system where mass in transferred via Roche lobe overflow resulting in direct impact onto the surface of the accretor. We model the stars as spherically symmetric rigid spheres and assume the mass transfer stream follows the trajectory of a ballistic point mass ejected from the inner Lagrangian point of the donor star. We approximate the mass transfer stream by discrete, non-interacting ballistic particles, conserving the linear and angular momentum of the three-body problem during ejection, accretion, and transport. We find that, contrary to popular assumptions, direct impact accretion can actually facilitate the transfer of angular momentum of the binary, direct impact mass transfer may increase the stability of such systems, significantly affecting the expected evolution timescales. We show the exchange of orbital angular momentum between the components of a binary system undergoing this process for a wide range of system parameters.

105.05

Vlbi Astrometric Orbit Solutions Of The Triple Systems Algol And Ux Arietis

Robert Lucien Mutel¹, W. M. Peterson¹, M. Guedel², M. Goss³

¹Univ. of Iowa, ²University of Vienna, Austria, ³NRAO.

11:00 AM - 11:10 AM

Room 615/617

Multi-epoch phase-referenced VLBI observations are a powerful technique to make sub-milliarcsecond astrometric measurements. We report on high-accuracy orbit and proper motion determination of the well-known active binaries Algol and UX Arietis, combining multi-epoch HSA and VLBA phase-referenced observations with archival VLBI datasets. We find that both Algol and UX Arietis are triple systems, For Algol, we refine the proper motion and outer orbit solutions, confirming the recent optical result of Zavala et al. (2010) that component C's position angle had been reported in error by 180 deg. For UX Arietis, we find a third component orbital solution that accounts for previous VLBI reports of an acceleration term in the proper motion fit.

105.06

Multi-wavelength Observations Of The Psr B1259-63/ Ss 2883 Be Star Periastron In 2010

Aous Abdo¹, Fermi LAT collaboration, S. Johnston², E. Grundstrom³, M. Roberts⁴

¹Naval Research Laboratory, ²ATNF, Australia, ³Vanderbilt University, ⁴Eureka Scientific.

11:10 AM - 11:20 AM

Room 615/617

PSR B1259-63/SS 2883 is a unique binary system consisting of a 47.7 ms radio pulsar orbiting a massive (10 - 15 M☉) Be companion star. The pulsar orbits the companion star with a period of ~3.4 years in a highly eccentric orbit. We have scheduled a coordinated radio, IR, optical, X-ray, and GeV gamma-ray observing campaign for the December 2010 periastron passage. This is the first periastron since the launch of the Fermi Gamma-ray Space Telescope and thus provides for the first time the opportunity to

observe the passage of the source through the Be stellar disk at GeV energies with such a sensitive instrument. We will present results from our multi-wavelength campaign.

105.07

Low-Frequency Oscillations in Global Simulations of Black Hole Accretion

Sean M. O'Neill¹, C. S. Reynolds², M. C. Miller², K. Sorathia³

¹University of Colorado at Boulder/JILA, ²University of Maryland, College Park/Joint Space Science Institute (JSI), ³University of Maryland, College Park.

11:20 AM - 11:30 AM

Room 615/617

We present the results of a numerical exploration of low-frequency variability in black hole accretion disks. Specifically, we have conducted a global, magnetohydrodynamic simulation of a thin, magnetized accretion flow that evolves for over 1,500 inner disk orbits. We have identified in this simulation the presence of dynamo cycles that manifest themselves predominantly as oscillations in the azimuthal magnetic field over timescales ten to twenty times longer than the local orbital period. Interestingly, these cycles occupy discrete frequencies that in many instances share power across broad radial ranges. We also connect the simulated dynamo cycles to several properties of observed low-frequency quasiperiodic oscillations in galactic black hole binary systems, noting that the cycles have the appropriate frequencies and narrow-band profiles and that they are located in a region associated with X-ray emission in real systems. This work clearly illustrates that magnetized disk dynamos can exhibit variability on timescales much longer than any timescale that would emerge from test particle considerations.

Funding for this work has been supplied by the NSF, NASA, and the Maryland-Goddard Joint Space Science Institute (JSI).

106 *AGN, QSO, Blazars I* Oral Session *Room 618/620*

106.01

Discovery Of A Radio-selected Z ~ 6 Quasar

Gregory Zeimann¹, R. H. Becker¹, R. L. White², S. A. Stanford³

¹UC Davis, ²Space Telescope Science Institute, ³Lawrence Livermore National Laboratory.

10:00 AM - 10:10 AM

Room 618/620

High redshift (z>5.7) represent some of the earliest and brightest objects in the Universe. These distant super-massive black holes are important in the study of galaxy evolution and the re-ionization epoch. Much of the ~60 known z>5.7 quasars are optically-selected with red i'-z' colors and blue z'-J colors. Optical-selection may miss a substantial population of reddened quasars (red z'-J colors) that can be found through radio-selection. McGreer et al. (2006) discovered a z=6.21 radio-selected quasar with colors that placed it outside of the usual optical-selection. We present the discovery of only the second radio-selected z>5.7 quasar known (z=5.92). We also discuss the implications of the discovery and future efforts.

106.02D The Hot Environments of X-shaped Radio Galaxies Edmund J. Hodges-Kluck¹, C. S. Reynolds¹

¹University of Maryland. 10:10 AM - 10:30 AM Room 618/620

X-shaped radio galaxies (XRGs) are unusual radio galaxies with a second pair of inactive lobes in addition to the canonical double-lobed source. The origin of the inactive lobes is not understood, and two dramatically different hypotheses have been proposed: either they are the result of a rapid reorientation of the AGN jet axis (possibly due to a supermassive black hole merger---XRGs have been held up as a predictor of merger rates) or they are produced by the deflection of relativistic lobe plasma flowing back (backflow) from the "hot spot" terminal shocks in the active lobes. These hypotheses have been explored by radio and optical observations, but the backflow hypothesis relies on the hot ISM or intragroup/intracluster medium to shape the radio source. In this work, we have studied the effect of the hot medium with Chandra and 3D hydrodynamic modeling of extragalactic radio sources. We present these results and argue that while the properties of the hot gas atmospheres are important, the backflow hypothesis needs to be modified before it can successfully explain XRG morphology. We also demonstrate that X-ray observations can be used to constrain the rapid reorientation model using one particular XRG. This research was funded in part by Chandra grants GO89109X, GO90111X, and GO011138A.

106.03D

Fermi Large Area Telescope Observations of a Candidate Young Radio Source

William McConville¹, L. Ostorero², R. Moderski³, L. Stawarz⁴, C. C. Cheung⁵, Fermi LAT Collaboration ¹NASA GSFC / University of Maryland, ²Dipartimento di Fisica Generale ``Amedeo Avogadro'', Universita degli Studi di Torino, Italy, ³Nicolaus Copernicus Astronomical Center, Poland, ⁴Institute of Space and Astronautical Science (ISAS), Japan Aerospace Exploration Agency (JAXA), Japan, ⁵Space Science Division, Naval Research Laboratory.

10:30 AM - 10:50 AM

Room 618/620

Using 19 months of Fermi LAT data, we investigate the gamma-ray properties of the radio-loud active galaxy 4C+55.17 (z=0.896) and re-examine its classification as a guasar-hosted blazar, considering instead its possible nature as a gamma-ray emitting young radio source. The active galaxy 4C+55.17 has a history of gamma-ray observations dating back to the EGRET era. Commonly classified as a Flat Spectrum Radio Quasar (FSRQ) due to its radio spectral shape and broad optical emission lines, the association of the EGRET source with 4C+55.17 remained tentative at the time, as the source exhibited spectral and morphological properties that were unlike any of the other bright gamma-ray blazars. With the improved angular resolution and sensitivity of the Large Area Telescope on board the Fermi Gammaray Space Telescope, the association of the gamma-ray source with 4C+55.17 is now confirmed due to the precise gamma-ray localization. An investigation of the gamma-ray properties of this source has revealed it to be an atypical member of the gamma-ray emitting FSRQ's, with an unusually hard and non-variable gamma-ray spectrum which extends up to the observed photon energies of 145 GeV despite its considerably high redshift for a very-high energy (>100 GeV) emitter. We further show that the high energy (>100 MeV) spectrum of this source may be formally extrapolated into the detectable range of ground-based Cherenkov telescopes, making it a compelling candidate for very-high energy observations, and in particular for future studies of the extragalactic background light.

The Sudden Death Of The Nearest Quasar

Kevin Schawinski¹, D. A. Evans², S. Virani³, M. Urry¹, W. C. Keel⁴, P. Natarajan¹, C. J. Lintott⁵, A. Manning⁴, P. Coppi¹, S. Kaviraj⁶, S. Bamford⁷, G. I. G. Jozsa⁸, M. Garrett⁸, H. van Arkel⁸, P. Gay⁹, L. Fortson¹⁰ ¹Yale University, ²MIT, ³James Madison University, ⁴University of Alabama, ⁵Oxford University, United Kingdom, ⁶Imperial College, United Kingdom, ⁷University of Nottingham, United Kingdom, ⁸ASTRON, Netherlands, ⁹Southern Illinois University Edwardsville, ¹⁰University of Minnesota.

10:50 AM - 11:00 AM

Room 618/620

Galaxy formation is significantly modulated by energy output from supermassive black holes at the centers of galaxies which grow in highly efficient luminous quasar phases. The timescale on which black holes transition into and out of such phases is, however, unknown. We present the first measurement of the shutdown timescale for an individual quasar using X-ray observations of the

nearby galaxy IC 2497, which hosted a luminous quasar no more than 70,000 years ago that is still seen as a light echo in `Hanny's Voorwerp', but whose present-day radiative output is lower by over 4 orders of magnitude. This extremely rapid shutdown provides new insights into the physics of accretion in supermassive black holes, and may signal a transition of the accretion disk to a radiatively inefficient state.

106.05

Black Holes and Starbursts in the Cosmic Web: Clustering and Evolution of Quasars and Submillimeter Galaxies

Ryan C. Hickox¹, A. D. Myers², Bootes Survey Collaboration

¹Durham University, United Kingdom, ²University of Illinois.

11:00 AM - 11:10 AM

Room 618/620

The growth of massive galaxies and their central supermassive black holes is linked to the their surrounding dark matter halos, whose masses can be inferred from measurements of spatial clustering. I will present a a novel technique for deriving real-space clustering using full photometric-redshift probability distributions, and discuss a recent study using this technique to measure clustering of dust-obscured (Type 2) and unobscured (Type 1) luminous quasars. I will present a similar measurement of the clustering of submillimeter galaxies, and will place the results in context of current models for the co-evolution of quasars and rapid starbursts. Finally I will briefly point toward future observational opportunities with *Herschel* and the proposed *Wide Field X-ray Telescope* mission. RCH is funded by an STFC Postdoctoral Fellowship.

106.06

M94 As A Unique Testbed For Black Hole Mass Estimates At Low Luminosities

Anca Constantin¹, A. C. Seth²

¹James Madison University, ²Harvard-Smithsonian Center for Astrophysics.

11:10 AM - 11:20 AM

Room 618/620

The newly discovered broad Halpha emission line in the nuclear spectrum of M94, which is unambiguously associated with X-ray, radio, and variable UV compact source detections, identifies this object as one of the least luminous accretion-type LINERs discovered thus far, and therefore, an important example of accretion at extremely low levels. Its true nature remains however ambiguous, mainly because of our inability to estimate its black hole mass. We present our comparison of four independent black hole mass estimates that reveal a discrepancy of two orders of magnitude between the value predicted by the Mbh-sigma relation and the value toward which methods based on emission activity in optical, mid-IR and X-rays, converge. If M94's black hole mass obeys these three latter methods that have not been verified in the low luminosity regime exhibited by this system, we have revealed the best case for an actively accreting intermediate mass black hole. In addition, this object would clearly violate the M-sigma relation. We discuss possible resolutions of this conundrum.

106.07

Testing the Consistency of Stellar and Gas Dynamical Black Hole Mass Measurements in AGNs Jonelle Walsh¹, A. J. Barth¹, R. C. E. van den Bosch², M. Sarzi³, J. C. Shields⁴

¹University of California, Irvine, ²Max-Planck Institut für Astronomie, Germany, ³University of Hertfordshire, United Kingdom, ⁴Ohio University.

11:20 AM - 11:30 AM

Room 618/620

NGC 3998 and NGC 4203 are two nearby S0 galaxies with LINER nuclei. The mass of the black hole in NGC 3998 has been measured previously through gas dynamical modeling of the emission-line disk using HST/STIS observations, while a gas dynamical measurement of the black hole mass in NGC 4203 is currently in progress. As both objects are also good targets for stellar dynamical modeling, they provide an excellent opportunity for the direct comparison of black hole mass measurements via the stellar and gas dynamical techniques. This necessary consistency check has so far only been attempted on a few galaxies with limited results. We will present laser guide star adaptive optics observations of NGC 3998 and NGC 4203 with the integral field spectrograph OSIRIS on the Keck II telescope. We measure high resolution stellar kinematics from the K-band CO bandheads, resolving the black hole sphere of influence. Additional large-scale observations of the stellar kinematics were taken at multiple slit positions with LRIS on the Keck I telescope and with the integral field spectrograph VIRUS-P on the 2.7m telescope at the McDonald Observatory. We will present preliminary results from the stellar dynamical modeling and constraints on the black hole masses.

107

Hydrogen Epoch of Reionization Arrays (HERA): Progress and Planning Special Session *Room 611/612*

107.01

Hydrogen Epoch of Reionization Arrays: Introduction Jacqueline N. Hewitt¹ ¹*MIT.* 10:00 AM - 10:06 AM *Room 611/612* The prospect of observing the Epoch of Reionization (EoR) that marks the end of the Dark Ages and the onset of structure formation is currently of great interest in astrophysics. The 21cm line of neutral

onset of structure formation is currently of great interest in astrophysics. The 21cm line of neutral hydrogen is a particularly promising probe. A sequence of Hydrogen Epoch of Reionization Arrays (HERA) has been proposed to provide measurements of EoR structures with increasing fidelity and depth as capability improves. The current first generation of HERA arrays is under construction or starting operation, and we can now begin to address the technical challenges of the next generation. I summarize the observational signatures targeted by the sequence of arrays, and identify some of the technical challenges.

107.02 Exploring the Dawn of Structure with the Redshifted 21 cm Signal Jonathan $\mbox{Pritchard}^1$

¹*Harvard University.* 10:06 AM - 10:15 AM

Room 611/612

The first billion years of the Universe contains the formation of the first galaxies and reionization. This period lies beyond the current observational frontier presenting challenges to theory and observation. Low frequency radio observations of the redshifted 21 cm line of neutral hydrogen will be key in developing our understanding of this period. In this talk, I will describe two aspects of the 21 cm signal from the period of "cosmic dawn": the global 21 cm signal and 21 cm fluctuations. I will discuss what can be learnt about the first galaxies and reionization from this technique and explore some of the challenges and opportunities ahead for global 21 cm experiments.

107.03

Extracting The Astrophysics Of The First Sources From The 21 Cm Global Signal Jonathan R. Pritchard¹, A. Loeb¹ ¹CfA.

10:15 AM - 10:21 AM

Room 611/612

Low frequency radio observations of the redshifted 21 cm line of neutral hydrogen have the potential to open a new window into the period from redshift z=6-30 when the first galaxies formed and reionization occurred. Single dipole experiments targeted at the frequency evolution of the 21 cm global signal are likely to provide the first constraints on this epoch. In this talk, I discuss the science of this signal and quantify the prospects for these instruments using a Fisher matrix based approach. I will show that there is considerable room for these simple experiments to constrain the star formation rate and production of X-ray and UV photons by the first luminous sources, provided that issues of calibration, RFI, and the ionosphere can be controlled.

107.04

The Low-Frequency Array (LOFAR) and EoR Key-Science Project

Leon V. E. Koopmans¹, A. G. de Bruyn², M. Brentjens², S. Zaroubi¹ ¹*Kapteyn Astronomical Institute, Netherlands,* ²*ASTRON, Netherlands.* 10:21 AM - 10:32 AM *Room 611/612*

The Low-Frequency ARray (LOFAR) is a novel radio-telescope facility with its core and operation center in the Netherlands. LOFAR is one of several current pathfinders toward SKA. One of LOFAR's key science projects is the detection and characterization of the redshifted 21-cm emission from neutral hydrogen coming from the Epoch of Reionization and Dark Ages at redshifts beyond 6. With role-out of the core and outer stations in the Netherlands and related computational facilities nearing completion, science operations are expected to commence soon. I will present a short overview of the current status of LOFAR and that of our Epoch-of-Reionization Key Science Project.

107.05

The GMRT EoR Experience

Ue-Li Pen¹, T. Chang² ¹*CITA, Canada,* ²*CITA/ASIAA, Canada.* 10:32 AM - 10:43 AM

Room 611/612

The Giant Metrewave Radio Telescope (GMRT) Epoch of Reionization Project has been actively searching for the 21cm signal from 7.5<z<9.5. We report on the current status, lessons learned, and future initiatives.

107.06

Results from 16 and 32 Antenna PAPER Deployments

Aaron Parsons¹, D. C. Backer¹

¹UC, Berkeley. 10:43 AM - 10:54 AM Room 611/612

We present observational results from 16- and 32-antenna deployments of the Precision Array for Probing the Epoch of Reionziation (PAPER) in Green Bank, West Virginia, and the Karoo Desert of South Africa. We discuss a novel technique for accessing the 3-dimensional power spectrum of reionization using these observations, and present new constraints on the amplitude and redshift of the peak 21cm fluctuations from cosmic reionization. We go on to discuss the impacts of systematics and foregrounds on these measurements and describe our next steps going forward.

107.07

Results From MWA

Miguel F. Morales¹, MWA collaboration ¹University of Washington. 10:54 AM - 11:05 AM *Room 611/612* The Murchicon Widefield Array (MWA) is

The Murchison Widefield Array (MWA) is a US-Australia-India low frequency observatory optimized for Epoch of Reionization measurements. This talk will review the current state of the Murchison Widefield Array and showcase results from the 32 antenna prototype.

107.08

Results From EDGES

Judd D. Bowman¹, A. E. E. Rogers² ¹*Arizona State University,* ²*MIT Haystack Observatory.* 11:05 AM - 11:14 AM

Room 611/612

The Experiment to Detect the Global Epoch of Reionization Signature (EDGES) has constrained the duration of reionization to span a redshift interval longer than dz>0.07 at 95% confidence, assuming reionization occurred between redshifts 6<z<13. The instrument measured the all-sky radio spectrum between 100 and 200 MHz with 10 mK sensitivity at the Murchison Radio-astronomy Observatory (MRO) between August and November, 2009. Rapid reionization would leave a characteristic step in the all-sky spectrum due to the disappearance of redshifted 21 cm emission from neutral hydrogen gas when it was ionized. No evidence for a sharp step was found in the observations. I will present the latest results and future plans for probing the reionization history and earlier epoch of first light in more detail with EDGES.

The Dark Ages Radio Explorer (DARE)

Jack O. Burns¹, J. Lazio², J. Bowman³, R. Bradley⁴, C. Carilli⁴, S. Furlanetto⁵, G. Harker¹, A. Loeb⁶, J. Pritchard⁷

¹Univ. of Colorado at Boulder, ²JPL, ³Arizona State University, ⁴NRAO, ⁵UCLA, ⁶Harvard University, ⁷CfA. 11:14 AM - 11:20 AM

Room 611/612

"What were the first objects to light up the universe, and when did they do it"? (NRC, 2011). These are among the most fundamental questions in modern astrophysics and cosmology as articulated in the recent NRC report, New Worlds, New Horizons in Astronomy and Astrophysics. The Astro2010 Decadal Survey singles out this epoch as one of the top three science objectives for the coming decade. The birth of the first stars and black holes - the end of the Dark Ages or the "Cosmic Dawn" - is one of the truly transformative events in the history of the Universe. It provides the key connection between observations of the extraordinarily smooth Universe 400,000 years after the Big Bang seen via the Cosmic Microwave Background, and telescopic images that reveal the wealth of structures and galaxies seen today. Unfortunately, this epoch has remained tantalizingly out of reach for decades and its exploration requires fundamentally new techniques. With the Dark Ages Radio Explorer (DARE), we will investigate this early epoch of the Universe (~80-350 million years after the Big Bang) for the first time using the sky-averaged, redshifted 21-cm Background (z=13-35) arising from the time when the first stars and black holes appeared in the Universe. DARE consists of a pair of tapered dipole antennas in lunar orbit operating in the shielded zone above the farside at 40-120 MHz. In this talk, we will discuss the science objectives and the instrument package for DARE.

107.10

Hydrogen Epoch of Reionization Arrays

Lincoln J. Greenhill¹, D. Backer²

¹*Harvard-Smithsonian, CfA,* ²*UC, Berkeley.*

11:20 AM - 11:30 AM

Room 611/612

Tomography of the intergalactic medium over a range of redshifts, backward through the Epoch of Reionization and into the Dark Age requires new generations of radio instruments, ones capable of detecting faint signatures of the

redshifted 21 cm Hydrogen line. I will discuss the Hydrogen Epoch of Reionization Array concept (HERA), which was proposed in the Astro2010 process. A progression of larger and more scientifically capable arrays will target detection and characterization of multidimensional power spectra, and ultimately, direct imaging of discrete structures at higher and higher redshift. With the final stage corresponding to about a square kilometer of collecting area and a few kilometer geographic extent, the end-stage technical challenges will be substantial, in particular with regard to signal processing and calibration. Each step up in array size, will enable incremental deployment and demonstration of new technologies and techniques to achieve new science, starting with present-day pathfinders. At about an order magnitude larger scale, the next generation array is anticipated to be practical to build and operate at about the middle of the decade.

108 *Gamma Ray Bursts* Oral Session *Room 4C-3*

108.01D

Dust Properties of Gamma Ray Burst Host Galaxies

Adria C. Updike¹, D. H. Hartmann¹, D. A. Kann²

¹*Clemson University,* ²*Thuringer Landessternwarte Tautenburg, Germany.*

10:00 AM - 10:20 AM

Room 4C-3

With the intent of furthering our understanding of the dust properties of the universe as a function of redshift, we investigate the utility of using GRBs as probes of dust composition. Using the measured optical properties of graphite and silicate particles, we can reproduce the extinction observed in GRB spectral energy distributions (SEDs). The photometric SEDs of 78 GRBs with redshifts in the range 0 < z < 5 are fit according to this method, allowing us to measure the graphite and silicate column densities along the line of sight to the GRB, the visual extinction in the host frame, and, in cases where the hydrogen column density for that GRB has also been measured, the dust-to-gas ratio of the host galaxy. In addition, we present computational models of dust evolution in galaxies as a function of redshift. We compare the results of our observations to the predicted trends in the model and discuss the use of GRBs as probes of dust evolution and star formation.

108.02D

The Afterglows and Host Galaxies of Dust-Obscured Gamma-Ray Bursts

Daniel A. Perley¹, J. S. Bloom¹, S. B. Cenko¹, A. J. Levan², H. Chen³, N. R. Tanvir⁴ ¹UC, Berkeley, ²Univ. of Warwick, United Kingdom, ³U. Chicago, ⁴Univ. of Leicester, United Kingdom. 10:20 AM - 10:40 AM

Room 4C-3

While gamma-ray bursts and their host galaxies are normally assumed (and observed) to originate from low-extinction sightlines and from blue, low-mass galaxies, both of these conclusions are subject to large selection effects as a result of the need to detect an optical afterglow to locate the host galaxy and measure the redshift. Many GRBs have exceedingly faint optical afterglows, and only since the launch of Swift have follow-up observational capabilities been able to consistently localize their positions. Evidence from observations of a uniform sample of Swift GRBs indicates that the majority of these "dark" bursts are heavily extinguished by dust in their host galaxies. New results from our five-year Keck Observatory GRB Host Survey, along with recent infrared observations from Gemini-North and the Spitzer Space Telescope, identify the host galaxies of many dark bursts to be highly infrared-luminous and dusty sources, contrasting dramatically with the hosts of GRBs selected via optical afterglow positions. This may suggest that GRBs can form at higher metallicites, and trace cosmic star-formation more closely, than previously believed. In other cases, even extremely dust-obscured bursts have hosts that are quite blue, suggesting a large hidden obscured component can exist even in apparently dust-free galaxies.

108.03

Threshold for Extended Emission in Short Gamma-Ray Bursts Jay P. Norris¹, N. Gehrels², J. D. Scargle³ ¹University of Denver, ²NASA/GSFC, ³NASA/ARC. 10:40 AM - 10:50 AM

Room 4C-3

The initial pulse complex (IPC) in short gamma-ray bursts is sometimes accompanied by a softer, lowintensity extended emission (EE) component. In cases where such a component is not observed, it has not been clear if it is present but below detection threshold. Using Bayesian Block methods, we have measured the EE component and shown that it is present in one quarter of a Swift/BAT sample of 51 short bursts. We simulated bursts with EE to calibrate the BAT threshold for EE detection. The EE component would have been detected in nearly half of BAT short bursts if it were present, to intensities ~ 10^{-2} counts cm⁻² s⁻¹, a factor of five lower than actually observed in the bursts with EE. The 2-sigma upper on the ratio, R_{int} = average EE intensity to IPC peak intensity, for the average of those 39 bursts without an EE component, is R_{int} < 8 x 10^{-4} .

Our results (ApJ, 717, 2010) suggest that a physical threshold mechanism operates near $R_{int} \sim \text{few x } 10^{-3}$ - below which the EE component is not manifest - but do not necessarily favor two different progenitors for short bursts.

108.04

GRB 081029: A Step Towards Understanding Multiple Afterglow Components

Stephen Holland¹, M. De Pasquale², J. Mao³, T. Sakamoto⁴, P. Schade⁵, S. Covino³, P. D'Avanzo³, A. Antonelli⁶, V. D'Elia⁷, G. Chincarini³, F. Fiore⁷

¹CRESST/USRA/NASA/GSFC, ²MSSL, United Kingdom, ³INAF-OAB, Italy, ⁴NASA/GSFC, ⁵Max Planck Institute, Germany, ⁶INAF-RAO, Italy, ⁷INAF-OAR, Italy.

10:50 AM - 11:00 AM

Room 4C-3

We present an analysis of the unusual optical light curve of the gamma-ray burst GRB 081029 at a redshift of z = 3.8479. We combine X-ray and optical observations from Swift with optical and infrared data from REM to obtain a detailed data set extending from ≈ 0.1 ks to ≈ 100 ks after the BAT trigger, and from 10 keV to 1600 nm. The X-ray afterglow showed a shallow initial decay followed by a rapid decay after about 18 ks. The optical afterglow, however, shows an uncharacteristic rise at about 5 ks that has no corresponding feature in the X-ray light curve. The data are not consistent with a single-component jet. It is possible that there are multiple physical components contributing to the afterglow of GRB 081029.

108.05D

In Search for a Relation with Physical Origin for GRBs

Razieh Behkam¹

¹Arizona State University.

11:00 AM - 11:20 AM

Room 4C-3

Gamma-ray burst observations provide a great opportunity for cosmography in high redshift. Some tight GRB correlations are already known. The relations with physical origin will have a better potential to utilize GRBs for cosmography. Ryde (2004) showed that the prompt emission spectrum is interpreted as composition of a thermal component in addition to the non-thermal one. We show here that analysing the thermal component of the GRB prompt emission leads us to a well-correlated relation. We also perform monte carlo test and show that this correlation is acceptably insensitive to our assumptions. Our correlation looks similar to Ghilanda's in quality, and provides some physical insights to Ghirlanda's relation.

108.06 Nova V407 Cygni 2010: First Detection of GeV Gamma-rays from a Nova Kent S. Wood¹, C. C. Cheung², A. B. Hill³, P. Jean⁴, S. Razzaque² ¹NRL, ²NRC/NRL, ³LAOG, France, ⁴CESR, France. 11:20 AM - 11:30 AM *Room 4C-3* We report the Fermi-LAT discovery of variable >100 MeV gamma-ray emission from the optical nova

of the symbiotic star V407 Cygni in March 2010, the first detection of gamma-rays in the GeV band from any nova. The spectrum and light curve of the gamma-ray emission can be understood broadly as consequences of shock acceleration in the nova shell as it interacts with the dense ambient medium of the red giant companion. Viable gamma-ray production mechanisms via pi-0 decay from proton-proton interactions and inverse Compton scattering of the radiation from the red giant are outlined.

109

Galaxy Clusters: Intracluster Medium and Cluster Masses Oral Session *Room 609*

109.01

Cluster Mass Profiles from the Hectospec Cluster Survey (HeCS)

Kenneth J. Rines¹, M. J. Geller², A. Diaferio³

¹Western Washington University, ²Smithsonian Astrophysical Observatory, ³Universita di Torino; INFN, Italy.

10:00 AM - 10:10 AM

Room 609

The Hectospec Cluster Survey (HeCS) is a spectroscopic survey of a flux-limited sample of X-ray-selected galaxy clusters at 0.1<z<0.3 with MMT/Hectospec. We obtained 19,609 new redshifts in 56 clusters to measure velocity dispersions and mass profiles extending well into their infall regions. Infall regions are an important transition environment between isolated galaxies and cluster members. Infall patterns resembling those seen in low-redshift clusters are established in clusters by z=0.3. We present mass profiles of the clusters and use these to measure scaling relations between X-ray properties and galaxy dynamics. We also explore the relation between galaxy dynamics and measures of optical richness and total stellar luminosity. Understanding cluster scaling relations is critical for interpreting large surveys like SPT, eROSITA, and DES.

109.02D

Shock-Bubble Heating of the Intracluster Medium

Samuel H. Friedman¹, S. Heinz¹, E. Churazov²

¹University of Wisconsin, ²Max Planck Institute for Astrophysics, Germany.

10:10 AM - 10:30 AM

Room 609

Active galactic nuclei (AGN) Feedback via extragalactic jets requires a thermalization of the energy injected into the intracluster medium (ICM) in order for energy feedback to occur. Heinz and Churazov (2005) proposed a method using shock waves and previously inflated bubbles in the ICM to extract energy from the shock waves and turn the energy into rotational kinetic energy. This energy would decay and allow heating to occur elsewhere throughout the galaxy cluster. In this paper, we extend to three dimensions (3D) the previous work using hydrodynamic simulations. We also compare our results to previous related work done performed experimentally.

109.03D

How Non-thermal Processes in the Intracluster Medium Affect the Sunyaev-Zel'dovich Angular Power Spectrum

Nicholas Battaglia¹, J. Bond², J. Sievers², C. Pfrommer² ¹University of Toronto, Canada, ²CITA, Canada. 10:30 AM - 10:50 AM

Room 609

To compute a reliable thermal Sunyaev-Zel'dovich angular power spectrum, it is essential to properly model the intracluster gas from the cluster core out to twice the virial radius, where pressure support from kinetic energy is important. We explore how radiative cooling, supernova feedback, cosmic rays and a new model of the energetic feedback from AGN affect this intracluster gas using a large set of hydrodynamical TreePM-SPH simulations of the cosmic web in big periodic boxes. We find the power at high-l that ACT and SPT probe is sensitive to the feedback model, hence can constrain the theory of intracluster gas, in particular at the uncertain redshifts >0.8. The apparent tension between σ_8 from primary CMB power and from analytic SZ spectra inferred using ACT and SPT data is lessened with our AGN feedback.

109.04D

The Physical Origin of Intrinsic Scatter in the Cluster X-ray and SZ Scaling Relations

Hsiang-Yi Yang¹, P. Ricker¹, S. Bhattacharya², P. Sutter¹

¹University of Illinois at Urbana-Champaign, ²Los Alamos National Laboratory.

10:50 AM - 11:10 AM

Room 609

Clusters of galaxies are invaluable cosmological probes, but systematic biases and the form and evolution of scatter in the mass-observable relations need to be understood to obtain accurate mass estimates. We use N-body plus hydrodynamic simulations including different physical processes to study the impact of halo concentration, dynamical state, radiative cooling and AGN feedback on scatter in the X-ray temperature-mass and the SZ flux-mass (Y-M) scaling relations. We find that the variation in concentration is a significant source of scatter in both relations, which can be used to tighten the relations for better mass estimates. Contrary to intuition, the effect of dynamical state is statistically negligible. Due to the sensitivity of the SZ effect to cluster morphology and projection effect, we find that the Y-M scatter has positive skewness and kurtosis to a degree that can bias cosmological constraints assuming lognormality. Fortunately, because the errors in the SZ and X-ray relations are not correlated, cross-calibrations of cluster masses can be effective in identifying the outliers due to projection errors. The influence of additional gas physics in cluster cores such as radiative cooling and AGN feedback is also discussed.

109.05

More Powerful than a Speeding "Bullet"? New HST Images and Analysis of the Galaxy Cluster Merger Abell 2744

Dan A. Coe¹, R. Dupke², N. Benitez³, T. Broadhurst⁴, R. Massey⁵, A. Zitrin⁶, J. Merten⁷, E. Cypriano⁸, F. Braglia⁹, B. Frye¹⁰, M. Meneghetti¹¹, L. Moustakas¹², J. Rhodes¹², J. Krick¹³, L. Sodre⁸, J. Bregman², Y. Jimenez-Teja³, R. Bernstein¹⁴

¹STScI, ²U Michigan, ³IAA, Spain, ⁴UPV/EHU, Spain, ⁵Edinburgh, United Kingdom, ⁶Tel Aviv, Israel, ⁷Heidelberg, Germany, ⁸Sao Paolo, Brazil, ⁹UBC, Canada, ¹⁰USF, ¹¹INAF, Italy, ¹²JPL, ¹³SSC, ¹⁴Santa Cruz. 11:10 AM - 11:20 AM

Room 609

Abell 2744 is a galaxy cluster merger similar to the Bullet Cluster but more massive and somewhat more complex. A2744 exhibits an even larger (the largest observed) projected separation between dark matter and the stripped, shocked cluster gas (~54" ~240 kpc). We may even be witnessing a triple merger similar to "The Cosmic Train Wreck" (Abell 520) as evidenced in part by Chandra X-ray observations which reveal high temperature shock regions (as high as 15 keV) and a complicated structure. We have obtained new deep (16 orbit), multiband (BVI) HST/ACS images of A2744's core. These images reveal in detail several prominent strong gravitational lensing features due to the SE subcluster, and our lens modeling reveals many more (~30 total). Here we present these images and new "non-parametric" mass models of A2744 based on simultaneous fitting to strong + weak lensing data in the HST and ground-based images. We discuss the relative positions of the dark matter peaks, galaxies, and gas peaks and implications for limits on the self-interaction cross section of dark matter particles.

109.06

Resurrecting The Red From The Dead: Optical Properties Of BCGs In X-ray Luminous Clusters Chris Bildfell¹, H. Hoekstra², A. Babul¹, A. Mahdavi³

¹University of Victoria, Canada, ²Leiden Observatory, Netherlands, ³San Francisco State University. 11:20 AM - 11:30 AM

Room 609

Brightest Cluster Galaxies (BCG) reside deep inside luminous X-ray clusters and represent the most massive end of the galaxy mass function. As such they offer a unique perspective on current problems in both galaxy formation and cluster gas physics. Baryonic feedback processes like AGN and star formation along with radiative cooling are believed to be responsible for the scatter in X-ray cluster scaling relations and should also leave observable signatures in the BCG properties. A detailed study of BCGs can allow one to probe the interaction and relative importance of these critical baryonic processes. We present measurements of surface brightness and colour profiles for the BCGs in a sample of 48 X-ray luminous galaxy clusters. These data were obtained as part of the Canadian Cluster Comparison Project (CCCP).

We find that while most BCGs show monotonic colour gradients consistent with a decrease in metallicity with radius, 25% show colour profiles that turn bluer towards the centre (blue cores). We interpret this bluing trend as evidence for recent star formation. The excess blue light leads to a typical offset from the red sequence of 0.5 to 1.0mag in (g' - r'), thus affecting optical cluster studies that may reject the BCG based on colour. All of the blue-core BCGs are located within ~10kpc of the peak in the cluster X-ray emission. Furthermore, virtually all of the BCGs with recent star formation are in clusters that lie above the Lx-Tx relation. Based on photometry alone, these findings suggest that central star formation is a ubiquitous feature of BCGs in dynamically relaxed cool-core clusters. This implies that while AGNs and other heating mechanisms are effective at tempering cooling, they do not full compensate for the energy lost via radiation. This research was funded in part by NSERC.

110 *Strategies for Addressing Harassment and Prejudice* Special Session *Room 4C-4*

110.01

Building Respect and Inclusion in Astronomy - Strategies for Understanding and Overcoming Harassment.

Sheryl Bruff¹

¹Space Telescope Science Institute.

10:00 AM - 10:45 AM

Room 4C-4

Building a respectful and inclusive workplace, whether in universities, research centers, governmental agencies, etc., is critical to the production of great scientific work. Behaviors that divide or exclude, such as harassment, bias or prejudice, diminish our ability to fully gain the value of scientific intellect and creativity.

Harassing, biased and intolerable conditions can arise in a variety of interpersonal situations - working relationships, collegial partnerships, academic study, etc., where clear expectations and boundaries are not identified and established and/or where situational power and control are not managed appropriately. Historically, situations have often been ignored and/or rationalized rather than addressed simply because the perpetrator "did not mean it" or did not realize the impact of his/her behavior. Victims frequently suffered in silence out of rationalization or fear of reprisal. Identifying and addressing harassing behaviors in the workplace has become more complex and expansive over the past few decades. In today's workplace, these behaviors fall into these classifications and what to do when confronted by these behaviors. This session will focus on understanding:

•what is meant by harassment and prejudice

•what prohibited behaviors fall into these categories

•how to respond and protect yourself

•remedies and protections afforded by laws, policies and programs

•what to expect from your organization.

Scenarios from real life circumstances and options for responding to harassing situations will be presented for discussion and review.

110.02

What to do about Inappropriate Behavior Bernice Durand¹

¹University of Wisconsin. 10:45 AM - 11:30 AM

Room 4C-4

If you believe you are a victim of harassment, bias, or prejudice, your first need is to know what person you should confide in who would be qualified to help you understand and go through the process of resolving your difficult situation.

You will be best off if you have an accessible, trustworthy institutional infrastructure in place for dealing with inappropriate behavior. The exact nature of the infrastructure varies among institutions; but it starts with leadership from the top person in every unit, for example the university president, the dean, the department chair, and the research group leader.

A good "safety net" structure also includes a reliable system for reporting and addressing problems

before they escalate; an institutional "enforcer" who is widely known to mean business; and trainings and frequent publicity about the consequences of such behavior.

The components of a good structure, as well as some alternative routes to take if you don't have such a system, will be described in the contexts of different types of institutions; and you will learn the criteria for prohibited behaviors. There will be time for analysis and discussion of scenarios taken from real incidents, altered to protect privacy.

111

HAD IV History of Astronomy Oral Session Room 613/614

111.01

Report of Some Comets: The Discovery of Uranus and Comets by William, Caroline, and John Herschel Jay M. Pasachoff¹, R. J. M. Olson²

¹Williams College and Caltech, ²New-York Historical Society.

10:00 AM - 10:15 AM

Room 613/614

We report on the discovery and drawings of comets by William, Caroline, and John Herschel. The first discovery, by William Herschel, in 1781 from Bath, published in the *Philosophical Transactions of the Royal Society* with the title "Report of a Comet," turned out to be Uranus, the first planet ever discovered, Mercury through Saturn having been known since antiquity. William's sister Caroline was given duties of sweeping the skies and turned out to be a discovered from Slough between 1786 and 1797. In the process, we also discuss original documents from the archives of the Royal Society and of the Royal Astronomical Society. We conclude by showing comet drawings that we have recently attributed to John Herschel, including Halley's Comet from 1836, recently located in the Ransom Center of the University of Texas at Austin.

Acknowledgments: Planetary astronomy at Williams College is supported in part by grant NNX08AO50G from NASA Planetary Astronomy. We thank Peter Hingley of the Royal Astronomical Society and Richard Oram of the Harry Ransom Center of The University of Texas at Austin for their assistance.

111.02

The Herschels in Canada Peter Broughton¹

¹Royal Astronomical Society of Canada, Canada. 10:15 AM - 10:30 AM Room 613/614

William Herschel, the father of the astronomical dynasty, may possibly have lived in Canada. A couple of his descendants certainly did, and their lives and contributions to astronomy will be briefly discussed. Furthermore, some geographic features in Canada commemorate the Herschel name. Where these landmarks are and how they came to have this distinction will be described.

111.03

King Charles` Star: A Multidisciplinary Approach To Dating The Supernova Known As Cassiopeia A Martin Lunn¹, L. Rakoczy¹

¹Yorkshire Museum, United Kingdom. 10:30 AM - 10:45 AM

Room 613/614

Few astronomical phenomena have been as studied as the supernova known as Cassiopeia A. Widely believed to have occurred in the latter half of the seventeenth century, it is also thought to have gone unrecorded. This paper will argue that Cas A did not go unobserved, but in fact was seen in Britain on May 29, 1630, and coincided with the birth of the future King Charles II of Great Britain. This 'noon-day star' is an important feature of Stuart/Restoration propaganda, the significance of which has been widely acknowledged by historians and literary experts. The argument here, however, is that in addition the historical accounts provide credible evidence for a genuine astronomical event, the nature of which must be explained. Combining documentary analysis with an overview of the current scientific thinking on dating supernova, the authors put forward their case for why Charles' star should be recognized as a sighting of Cas A. Finally, it will be argued that a collaborative approach between the humanities and the sciences can be a valuable tool, not just in furthering our understanding of Cas A, but in the dating of supernovae in general.

111.04

The "Three York Astronomers" and the Royal Society of London

Linda M. French¹

¹Illinois Wesleyan Univ.. 10:45 AM - 11:00 AM

Room 613/614

John Goodricke, the discoverer of the periodicity of Algol and Delta Cephei; his mentor and collaborator Edward Pigott; and Edward's father Nathaniel Pigott flourished in York, England in the 1780's. All three made substantial contributions to astronomy. Nathaniel and Edward had determined the longitudes of the principal cities of the Low Countries before moving to York. Edward worked closely with Goodricke on the observations of Algol and discovered the variability of Eta Aquilae, a Cepheid, before Goodricke discovered Delta Cephei's behavior. All three corresponded with members of the Royal Society, including Nevil Maskelyne and William Herschel, yet the treatment accorded them differed widely. Nathaniel Pigott was elected a member of the Society in 1772. Goodricke received the Society's Copley Medal for his paper on the periodicity of Algol in 1783 at the age of nineteen. In 1786, after being nominated by Nathaniel Pigott, Goodricke was elected to membership in the Royal Society. Edward Pigott was apparently never nominated. Some possible reasons why Goodricke was lionized and Edward Pigott passed over will be explored.

This research was supported by an AAS Small Research Grant and by the Herbert C. Pollack Award of the Dudley Observatory.

111.05

The Historical 'Science Driver': Early Telescopes and Scientific Incentive. Peter Abrahams¹

¹*Historical Astronomy Division.*

11:00 AM - 11:15 AM

Room 613/614

The term 'science driver' was first used in the 1980s. The modern meaning of 'science' is far removed from its meaning in the first centuries of the telescope. It is anachronistic to refer to the 'science driver' of a historic telescope. However, there were scientific motivations behind many early telescopes, large reflectors in particular. The chronology of larger and improved telescopes will be placed in the context of the rationale for their creation. The evolution of scientific purpose of these instruments will be extracted and examined for patterns and significance.

111.06 Blind Astronomers Thomas A. Hockey¹

¹University of Northern Iowa. 11:15 AM - 11:30 AM

Room 613/614

The phrase "blind astronomer" is used as an allegorical oxymoron. However, there were and are blind astronomers. What of famous blind astronomers?

First, it must be stated that these astronomers were not martyrs to their craft. It is a myth that astronomers blind themselves by observing the Sun. As early as France's William of Saint-Cloud (circa 1290) astronomers knew that staring at the Sun was ill-advised and avoided it. Galileo Galilei did not invent the astronomical telescope and then proceed to blind himself with one. Galileo observed the Sun near sunrise and sunset or through projection. More than two decades later he became blind, as many septuagenarians do, unrelated to their profession. Even Isaac Newton temporarily blinded himself, staring at the reflection of the Sun when he was a twentysomething. But permanent Sun-induced blindness? No, it did not happen.

For instance, it was a stroke that left Scotland's James Gregory (1638-1675) blind. (You will remember the Gregorian telescope.) However, he died days later. Thus, blindness little interfered with his occupation.

English Abbot Richard of Wallingford (circa 1291 - circa 1335) wrote astronomical works and designed astronomical instruments. He was also blind in one eye. Yet as he further suffered from leprosy, his blindness seems the lesser of Richard's maladies.

Perhaps the most famous professionally active, blind astronomer (or almost blind astronomer) is Dominique-Francois Arago (1786-1853), director until his death of the powerful nineteenth-century Paris Observatory.

I will share other - some poignant - examples such as: William Campbell, whose blindness drove him to suicide; Leonhard Euler, astronomy's Beethoven, who did nearly half of his life's work while almost totally blind; and Edwin Frost, who "observed" a total solar eclipse while completely sightless.

112

Interstellar Medium: Dust Particles and Emission Oral Session *Room 608*

112.01

An Approach To Investigating Dust Properties In Galaxies Through Simulations Of Extinction Of Sne Ia Spectra

Susana E. Deustua¹, A. Cikota², K. Gordon¹

¹Space Telescope Science Institute, ²University of Zurich, Switzerland.

10:00 AM - 10:10 AM

Room 608

Because they are so bright, Type Ia Supernovae (SNeIa) are probably the most accurate distance indicators on cosmological scales. And, although SNeIa are not equally bright, they are standardizable candles through the known correlation between their peak brightness and the width of their light curves. However, the correlation fails for some SNeIa which can appear dimmer and redder either because of host galaxy dust extinction or perhaps due to intrinsic properties. We have undertaken a study to examine the effects of dust on SNe Ia observations, including investigating possible differences between the dust properties in galaxies, both nearby and at high redshifts. One of our goals with this
study is to investigate the uncertainties on SN Ia extinction values using multicolor data of nearby galaxies. We have taken advantage of

The Spitzer Infrared Nearby Galaxies Survey (SINGS), a comprehensive study of 75 nearby galaxies (Kennicutt et al. 2003) with good estimates of their dust masses (Draine et al. 2007). We combine this date with SNe Ia templates to bound the effects of extinction. To investigate high redshift galaxy dust properties in high-z galaxies we compare the simulated spectra to the PHASE extracted data set of 139 spectra of 124 Type Ia supernovae obtained at the VLT during the first three years of the CFHT Supernova Legacy Survey (Balland et al).

We discuss the methods used in our simulations and the significance of the results of this study based on comparing computed extinction for template spectra to published observational data of low and high redshift SNe Ia.

112.02D

Dust Formation and Evolution in Core Collapse Supernovae Jennifer E. Andrews¹

¹Louisiana State University. 10:10 AM - 10:30 AM

Room 608

Detection of large amounts of dust in high redshift galaxies suggest that core collapse supernovae (CCSNe) may play an important role in the dust budget of the universe. At an age of only 1Gyr, there has not been enough time for low-mass stars to form and evolve to the asymptotic giant branch, but there has been sufficient time for CCSNe, which quickly evolve and return their material to the surrounding interstellar medium. For the past three years, I have been following the Type IIP SNe 2007it and 2007od with Gemini, HST, and Spitzer to look for indicators of dust formation, which appear within the first few years of discovery. The data obtained have significant temporal and wavelength coverage, and the SNe show unusual and interesting characteristics. In both cases we are seeing evidence of CSM interaction in their spectral evolution, although neither was initially classified as a Type IIn. We found SN 2007it to be oxygen rich with 56Ni masses quite large for a Type IIP, while SN 2007od is oxygen poor with a very low 56Ni mass. Light echoes also seem to be present in both SNe. We estimate ~10⁻⁴ Msun of dust has formed in each SN, consistent with other CCSNe, but still smaller than needed to account for the amount of dust seen at high redshift.

This work has been supported by NSF grant AST-0707691 and NASA GSRP grant NNX08AV36H. This work was supported by Spitzer Space Telescope RSA 1415602 and RSA 1346842, both issued by JPL/Caltech.

112.03

Star Formation Rates From 8 Micron PAH Emission: Quantifying The Contamination From Old Star Excitation

Alison Faye Crocker¹, D. Calzetti¹, D. A. Thilker², KINGFISH Team

¹UMass Amherst, ²Johns Hopkins University.

10:30 AM - 10:40 AM

Room 608

Dust emission in the mid-infrared (MIR), mainly from polycyclic aromatic hydrocarbons (PAHs), is used as a star formation rate tracer at both low and high-redshifts. However, PAHs can be excited not only by young UV-emitting stars, but also by the softer radiation field of older stars. Yet no study quantifying the fraction and spatial distribution of this 'diffuse' MIR component has been performed. To do this, we compare the Spitzer 8 micron emission (stellar subtracted) to the distribution of the H α recombination line in a sample of SINGS spiral galaxies. Dust-corrected H α emission accurately traces star formation as only hot young stars can produce the required ionizing continuum (outside of the immediate environs of an AGN or strong shocks). The 8 micron and H α images show qualitative differences, with the H α appearing much more limited to clumpy HII regions and the 8 micron having a smoother appearance (after convolution to the same resolution). Considering only diffuse regions (i.e. ignoring HIIphot-identified HII regions), we see that the diffuse/total 8 micron emission ratio is significantly greater than the diffuse/total H α emission ratio. This difference implies that some of the PAH excitation in normal star-forming spiral galaxies is due to older stars (20% in the first galaxy analyzed, NGC 628). Applying identical techniques to the good-resolution FIR Herschel data on a similar sample of galaxies will provide an estimate of the FIR dust emission attributable to diffuse heating.

112.04

Observations of strong Diffuse Interstellar Bands in M31 and M33

Martin Cordiner¹, N. L. J. Cox², K. T. Smith³, C. J. Evans⁴

¹NASA Goddard Space Flight Center, ²Institute for Astronomy, K.U. Leuven, Belgium, ³School of Chemistry, The University of Nottingham, United Kingdom, ⁴UK ATC, Royal Observatory Edinburgh, United Kingdom.

10:40 AM - 10:50 AM

Room 608

We report the first detections of diffuse interstellar bands (DIBs) in absorption towards early-type supergiant stars in the Local Group spiral galaxies M 31 and M 33. The $\lambda\lambda$ 4430, 5705, 5780, 5797, 6203, 6269, 6283, 6379 and 6613 DIBs are detected at radial velocities matching the blue-shifted M 31 and M 33 Na I absorption lines. The overall spectrum of DIBs and the ratios of strengths between the different M 31 and M 33 DIBs are found to be similar to those typically observed in the Milky Way. These results are discussed in the context of the different interstellar physical and chemical conditions of these galaxies compared with the Milky Way, including the metallicity, the interstellar radiation field, the dust extinction properties and the PAH abundances. Some of the M 31 and M 33 DIB equivalent widths are found to be exceptionally large per unit reddening (E(B-V)) compared with those typically observed in the Galaxy. These results indicate that conditions in M 31 and M 33 are favourable for the production of the large organic molecules that are believed to be the carriers of at least some of the DIBs. A negative correlation is found in M 31 between the DIB strengths and the strength of the interstellar NUV radiation.

This work has been funded by the NASA Institute for Astrobiology, the Faculty of the European Space Astronomy Centre (ESAC), Queen's University Belfast, and the UK Engineering and Physical Sciences Research Council (EPSRC).

112.05

The Importance of Aluminum in Silicate Glasses

Arielle L. Newgard¹, A. Speck¹, A. Whittington¹, A. Hofmeister², J. Tartar¹ ¹University of Missouri - Columbia, ²Washington University. 10:50 AM - 11:00 AM

Room 608

It is well known that silicate dust plays an important role in many astrophysical environments with an emphasis in the literature on olivines and pyroxenes due to their lower condensation temperature. However these two types of silicates tend to be Al-free and it would be remiss to exclude the role of Al from silicate dust. For example, Al is seen in CAI (Ca-Al inclusions) in primitive meteorites and the Al is the fourth most abundant metal after Si, Mg, and Fe. However, we expand upon the currently presented knowledge of the role of Al in silicate dust by looking more closely at the structure (polymerization) represented in NBO/T ratio (Non-bridging oxygens to SiO4 tetrahedra). We present a sample of silicates

of known Al abundance and discuss how the Al affects these samples both physically and spectrally. Potential applications of these data are also discussed.

112.06

UV-Visible Laboratory Spectra Of Dust Analogs: Mg-silicates, Spinel, And Glasses Karly M. Pitman¹, A. M. Hofmeister², A. K. Speck³

¹Planetary Science Institute, ²Washington University - St. Louis, ³University of Missouri - Columbia. 11:00 AM - 11:10 AM

Room 608

There is a great need for UV-vis data to analyze many astronomical environments but past laboratory analog spectra in the UV-vis are insufficient to reliably determine the composition and structure of dust from astronomical observations and models. To address this need, we will present the spectral behavior of selected silicates, silicate glasses, and an oxide that may be present in space over the mid-UV to HST wavelength range λ =190-1100 nm. Priority compounds for this study are the Mg-rich crystalline silicates (forsterite Mg₂SiO₄; enstatite Mg₂Si₂O₆) that are predicted in abundance models and found in multiple objects (e.g., AGB stars, PNe, YSOs, comets, ultraluminous IR galaxies, O-rich stellar outflows, β -Pic, Herbig Ae/Be stars). We will also present new UV-vis data for the oxide spinel (MgAl₂O₄), relevant to presolar grains, chondritic meteorites, AGB, and SN. Finally, we will present UV lab data on silicate glasses to connect to complementary IR silicate glass data and assist in testing the hypothesis that the majority of interstellar dust in our own galaxy was formed in dark molecular clouds, rather than the outflows of evolved stars. By determining the UV properties of both crystalline and glassy silicates, we may be able to distinguish whether the ISM silicate is truly glass, and thus determine whether ISM dust is formed in situ. This work is supported through NSF AST-1009544.

112.07

The Alignment of Dust Grains With the Magnetic Field in Dense Regions of Taurus

Nicholas L. Chapman¹, P. Goldsmith², D. Li², D. Clemens³

¹Northwestern University, ²Jet Propulsion Laboratory, ³Boston University.

11:10 AM - 11:20 AM

Room 608

We present maps of the plane-of-sky magnetic field within two regions of the Taurus molecular cloud: one in the dense core L1495 and the other in a diffuse region for comparison. The field direction is measured from the polarization of background starlight seen through the cloud. Because our data are at near-infrared wavelengths, we are able to measure the polarization even in the densest portion of L1495. In this region, we find that the percentage polarization increases with column density, suggesting that the dust grains are aligned with the magnetic field to some significant depth in the cloud rather than grain alignment being confined to a thin surface layer. This is in contrast to some previous results in Taurus and other regions, but is consistent with a more recent analysis that showed that grain alignment by means of radiative torques could explain a correlation between polarization percentage and column density.

This work was supported by the Jet Propulsion Laboratory, California Institute of Technology and NSF grant AST-090930.

112.08 Hi-GAL Observations: Emissivity Spectral Index along the Galactic Plane Marcella Veneziani¹, D. Paradis¹ ¹SSC-Caltech. 11:20 AM - 11:30 AM

Room 608

Variations in the dust emissivity are critical for gas mass determination derived from far-infrared observations, but also for separating dust foreground emission from the Cosmic Microwave Background. Hi-GAL observations allow for the first time to study dust emissivity variations in the inner regions of the Galactic plane. We present emissivity spectral index maps derived from the Herschel PACS 160 and SPIRE 250, 350 and 500 micron data combined to the IRIS 100 micron data, and we analyze the spatial variations of the spectral index as a function of dust temperature and wavelength in the two Science Demonstration Phase Hi-GAL fields, centered at I=30deg and I=59deg. Applying two different methods, we determine both dust temperature and emissivity spectral index between 100 and 500 micron, at an angular resolution of 4 arcmin. Combining both fields, the results evidence variations of the emissivity spectral index are identical in both fields, i.e. 2.3 in the range 100-500 micron, for median dust temperature equal to 19.1 K and 16.0 K in the I=30deg and I=59deg field, respectively. Statistically, we do not see in the emissivity spectra any significant deviations from a power law between 100 and 500 micron. We show an inverse correlation between the emissivity spectral index and the dust temperature, found in previous analysis in various environments.

113

YSOs, Etc. I Oral Session *Room 604*

113.01

Fragmentation Of Cold Atlasgal Dust Clumps

Jagadheep D. Pandian¹, T. Troost², F. Wyrowski², J. P. Williams¹, F. Schuller², K. M. Menten² ¹Institute for Astronomy, ²Max Planck Institute for Radio Astronomy, Germany. 10:00 AM - 10:10 AM Room 604

The APEX Telescope Large Area Survey of the Galaxy (ATLASGAL) has revealed a large sample of dust continuum sources that are potential sites of high-mass star/cluster formation. This dataset, when combined with 70 and 24 micron data from the Spitzer MIPSGAL survey allows identification of sources at the earliest phases of star formation. One of the open questions in high-mass star formation is the nature of fragmentation in early evolutionary phases. To address this question, we have observed a sample of high-mass ATLASGAL sources that have no counterpart at 70 micron or 24 micron in MIPSGAL, at 345 GHz using the SMA in its compact configuration. The sources are chosen to have kinematic distances less than ~ 5 kpc, and consequently our observations probe scales down to 0.1 pc. We present initial results of this work and discuss the mass assembly from large scale dust clumps to small scale cores.

113.02

VLA Ammonia Observations of IRAS 16253-2429: A Very Young and Low Mass Protostellar System Jennifer J. Wiseman¹, M. Barsony², R. Sahai³

¹NASA / GSFC, ²Space Science Institute, ³NASA Jet Propulsion Laboratory.

10:10 AM - 10:20 AM

Room 604

IRAS 16253-2429, the source of the Wasp-Waist Nebula seen in Spitzer IRAC images, is an isolated, very low luminosity ("VeLLO") Class 0 protostar in the nearby rho Ophiuchi cloud. We present VLA ammonia mapping observations of the dense gas envelope feeding the central core accreting system. We find a flattened envelope perpendicular to the outflow axis, and gas cavities that appear to cradle the outflow

lobes as though carved out by the flow and associated (apparently precessing) jet. Based on the NH3 (1,1) and (2,2) emission distribution, we derive the mass, velocity fields and temperature distribution for the envelope. We discuss the combined evidence for this source as possibly one of the youngest and lowest mass sources in formation yet known.

113.03D

The Search For Pulsation In Young Low-mass Stars And Brown Dwarfs: A High-precision Photometric Census Of Variability At 3-5 Myr

Ann Marie Cody¹, L. Hillenbrand¹

¹Caltech.

10:20 AM - 10:40 AM

Room 604

In 2005, Palla & Baraffe proposed that brown dwarfs and very low mass stars (<0.1 solar masses) may be unstable to radial oscillations during the pre-main-sequence deuterium burning phase. With associated oscillation periods of 1-4 hours, this potentially new class of pulsation offers unprecedented opportunities to probe the interiors and evolution of low-mass objects in the 1-15 My age range. Furthermore, several previous reports of short-period variability have suggested that deuterium-burning pulsation is in fact at work in young clusters.

As part of my dissertation, I developed a photometric monitoring campaign to search for low-amplitude periodic variability in young brown dwarfs and very low mass stars. I will discuss the details of high-precision, high-cadence time series photometry in four young clusters, using meter-class telescopes from both the ground and space. The survey achieves sensitivity to periodic oscillations with photometric amplitudes down to several millimagnitudes. I will present the census of variability on timescales ranging from minutes to days in a sample of ~100 young, low-mass cluster members. While I find a dearth of photometric periods under 10 hours, the campaign's high time resolution and precision have enabled detailed study of diverse light curve behavior in the clusters: rotational spot modulation, accretion signatures, and occultations by surrounding disk material. Analysis of our data has led to the establishment of a lower limit for the time scale of photometry variability in young low-mass and substellar objects, an extension of the rotation period distribution to the brown dwarf regime, as well as a new study on the connection between variability and circumstellar disks in the Sigma Orionis cluster.

113.04

Using Spitzer IRS Spectroscopy to Characterize the Massive Young Stellar Objects in the G333 Massive Star Forming Region

Janet P. Simpson¹, A. S. Cotera¹, I. Bains², M. G. Burton³, M. Cunningham³, N. Lo⁴

¹SETI Institute, ²Swinburne University, Australia, ³University of New South Wales, Australia, ⁴University of Chile, Chile.

10:40 AM - 10:50 AM

Room 604

Mid-infrared spectroscopy provides unique and crucial information that can be used to characterize massive young stellar objects (MYSOs) and resolve questions regarding the evolutionary states of these objects. We have used the Spitzer Space Telescope Infrared Spectrograph in the Short-Low, Short-High, and Long-High modules (5-36 micron) to map the thirteen very red sources that we found in Spitzer IRAC (GLIMPSE) and MIPS (MIPSGAL) images of the G333 giant molecular cloud. The objects, which have luminosities ranging from ~2X10³ Lsun to ~5X10⁴ Lsun, are divided into two groups: seven MYSOs associated with extended emission in IRAC band 2 at 4.5 micron ("outflow sources", also known as "EGOs" or "green fuzzies") and six MYSOs that have extended emission in all IRAC bands peaking at the longest wavelengths ("red sources"). All the YSOs associated with outflows show evidence of massive

envelopes surrounding the star, which produce deep silicate absorption features and absorption by ices at 6.0, 6.8, and 15.2 micron. There is shocked gas associated with the 4.5 micron emission, as seen by the presence of [S I] 25 micron line emission in over half of the outflows (but not by any associated H2 line emission, as has been suggested elsewhere). For four of the red sources, our spectral maps show that there are ionized neon and sulfur lines concentrated to the YSO locations, from which we infer that these red YSOs can already ionize H II regions. For several objects of both types, the lines from the highly excited Ne++ ions peak at some distance from the peak of the low excitation lines. We conclude that both types of MYSO have outflows that produce shocked gas and that the outflow MYSOs, which have slightly cooler spectral energy distributions than the red YSOs, are younger than the H II region producing, red MYSOs.

113.05

A High-resolution Study of the Spectrum of HD 190073 (V1295 Aql)

Charles R. Cowley¹, S. Hubrig²

¹Univ. of Michigan, ²Astrophysikalisches Institut Potsdam, Germany.

10:50 AM - 11:00 AM

Room 604

Detailed abundance work on Herbig Ae stars began in the last decade. Acke and Waelkens's (A&A, 427, 1009, 2004, henceforth AW) study is exemplary. We report results for HD 190073 (V1295 Aql), based on significantly better spectroscopic material: 8 averaged HARPS spectra from the ESO archive (RP=110,000, Fourier-filtered, S/N 200-350).

There is significant line emission, not only in the Balmer cores, but also in myriad metal lines. We assume with AW that abundances may be derived from equivalent widths of lines not involved with emission, taken to belong to a photosphere not badly deviant from models. We confirm AW for HD 190073, in that consistent results may be obtained from two stages of ionization of several elements, and internal excitations within an ionization

stage. We adopt Teff=9100K, and log(g)=3.0, slightly different from AW's 9250K and log(g)=3.5. The adopted parameters give fits to the wings of the Balmer lines. We find no indication of anomalous saturation found for HD 101412 (A&A, in press, arXiv:1008.1601), in spite of the far more prominent emission of HD 190073. The latter star is more massive, and younger, and probably observed nearly pole on.

The iron abundance is closely solar, but we find a larger nitrogen excess than AW, +0.8 dex. Sodium is in excess by the same amount, while zinc is overabundant by 0.3 dex.

The emission-line spectrum was described recently by Catala, et al. (A&A, 462, 293, 1967). We model the region as a hot slab above an approximate stellar photosphere. Metallic emission below the Balmer jump is often optically thick, while the line centers rarely approach unit optical depth above it.

113.06

Constraining the Size of the Solar Nebula

Katherine A. Kretke¹, H. F. Levison¹

¹Southwest Research Institute.

11:00 AM - 11:10 AM

Room 604

Observations indicate that the circumstellar gaseous disks around young stars vary significantly in size, ranging from 10s to 1000s of AU. As we try to unravel the events leading to the formation of our own solar system, we would like to understand the properties of our own primordial disk. Fortunately, the dynamics of objects in the Kuiper belt provide interesting constraints. After Jupiter formed, it must have scattered a significant number of planetesimals into eccentric orbits. If there had been a massive,

extended protoplanetary disk at that time, then the disk would have excited Kozai oscillations in the scattered objects, driving some into high-inclination, low-eccentricity orbits. The dissipation of the gaseous disk would strand some objects in these high-inclination orbits; orbits that are stable on Gyr timescales. The fact that we have yet to observe Kuiper belt objects on these orbits therefore places a strict limits size of the disk at the time of planet formation, revealing important information about the environment from which our solar system emerged.

113.07

The Evolution Of The Solar Flux: Quantitative Estimates For Planetary Studies

Mark Claire¹, J. Sheets¹, M. Cohen², I. Ribas³, D. Catling¹ ¹Univ. of Washington, ²Univ. of California, ³Institut de Ciencies de l'Espai, Spain. 11:10 AM - 11:20 AM

Room 604

Understanding changes in the solar flux over the age of the solar system is vital for understanding the evolution of planetary atmospheres. We describe a numerical parameterization for wavelength dependent changes to the non-attenuated solar flux appropriate for most times and places in the solar system. We combine published data from the Sun and solar analogs to estimate enhanced FUV and Xray fluxes for the young Sun, describe a new parameterization for the near UV where both the chromosphere and photosphere contribute to the flux, and use Kurucz models to estimate variable visible and infrared fluxes. The parameterization, a series of multipliers relative to the modern top of the atmosphere flux at Earth, is valid from 2 nm through the infrared, and from 0.6 Gyr through 6.7 Gyr, and is extended from the solar zero age main sequence to 8.0 Gyr subject to additional uncertainties. The parameterization is applied to a representative modern day solar flux, providing quantitative estimates of the wavelength dependence of solar flux for a range of paleodates that are relevant to studies of the chemical evolution of planetary atmospheres. We validate the code by comparison to the solar proxies Kappa1 Ceti and EK Draconis, and provide an Monte Carlo analysis of the uncertainties due to measurement error, unknown stellar ages, and intrinsic variability.

114

Starburst Galaxies Oral Session Room 606

114.01

Distribution of Star Formation in Distant Galaxies

Marianne Y. Takamiya¹, I. Cunnyngham¹, C. Willmer², M. Chun³, M. Young⁴, MTakamiyaUHH ¹Univ. of Hawai - Hilo, ²Steward Observatory, University of Arizona, ³Institute for Astronomy, UH, ⁴Indiana University.

10:00 AM - 10:10 AM Room 606

The distribution in the Star Formation Rates (SFR) of distant galaxies are presented based on integral field unit observations with the GMOS-IFU on Gemini. Galaxies from the HDF and SA68 with redshifts between 0.6 and 0.8 were selected based on the presence and strength of H-beta and [OII]3727 emission lines measured in Keck/LRIS slit spectra. From the sample of 10 galaxies, only the bluest sources show [OII] in the IFU data regardless of total galaxy luminosity. The [OII] emission is distributed in an arc-like structure several kiloparsecs in scale. We posit that the brightest galaxies in the sample do not show significant emission lines possibly because the star formation is distributed uniformly across the disk at a lower intensity than the detection limit of the IFU. Moreover, the amount of extinction in brighter galaxies is likely to be larger and thus the star-forming sites may be highly obscured

contributing to the non-detection of these optical lines in the IFU. At this redshift range, we identify two distinct modes of star formation among this seemingly homogenous group of z=0.7 star-forming galaxies. The sample of galaxies is being extended to include more IFU spectra from the Gemini Science Archive. By increasing the sample, we expect to characterize these modes of star formation which could be high-redshift counterparts of the U/LIRGs and dwarf starburst galaxies like NGC 1569 and NGC 4449. The authors wish to acknowledge funds provided by the Cottrell Research Corporation and the National Science Foundation (AST 0909240).

114.02D

OH Masers from Andromeda to the Peak of Cosmic Star Formation Kyle Willett 1

¹University of Colorado.

10:10 AM - 10:30 AM

Room 606

OH masers are well-known astronomical phenomena in which 18-cm radiation is amplified through the process of stimulated emission. My dissertation research focuses on the study of OH masers in multiple environments. The first portion is a Spitzer spectroscopic study of OH megamaser host galaxies. Several infrared properties of the host galaxy are shown to strongly correlate with the presence of an OH megamaser. These requirements include a smooth, optically thick dust environment and dust temperatures of 40-100 K in the circumnuclear region. I also demonstrate that the presence of an AGN highly selects against the presence of a megamaser - OHM hosts are dominated by starburst galaxies. I also use combined radio and IR data to make the first detailed test of an OH pumping model using the global parameters of the host galaxies. Based on our analysis, current models must be updated to include much higher optical depths and a variety of dust geometries. Secondly, I describe results from a new high-redshift search for OH megamasers using the Green Bank Telescope. The combination of new OHM detections and upper limits are used to construct an expanded OH luminosity function. Since the presence of an OHM traces both merging galaxies and extreme star formation, megamasers can serve as a powerful probe of galaxy evolution across cosmic time. The discovery of OHMs at z~1 is crucial for achieving this goal. Finally, I describe results of a new and complete OH survey of the Andromeda galaxy (M31). The goal of this survey is to find masers that can be used to measure M31's proper motion, which is as yet unknown. Any constraints on this will significantly impact our understanding of the Local Group's dynamics, history, and future evolution.

114.03

Obscured Starburst Activity in High Redshift Clusters and Groups

Dale Kocevski¹, B. Lemaux², L. Lubin², R. Gal³

¹University of California, Santa Cruz, ²University of California, Davis, ³Institute for Astronomy, University of Hawaii.

10:30 AM - 10:40 AM

Room 606

Using Spitzer MIPS 24um imaging and extensive Keck spectroscopy we have found evidence for environmentally triggered starburst activity within six clusters and groups at z~0.9. I will show that the density of 24um-detected galaxies in the cluster environment is nearly twice that of the surrounding field at this redshift and that this overdensity scales with the cluster's dynamical state. The 24um-bright members often appear optically unremarkable and exhibit only moderate [OII] line emission due to severe obscuration. Although their spatial distribution suggests they are an infalling population, a close examination of their spectral properties, morphologies and optical colors indicate they are not simply analogs of the field population that have yet to be quenched. Using stacked DEIMOS spectra, we find

the 24um-detected cluster and group galaxies exhibit elevated levels of Balmer absorption compared to galaxies undergoing normal, continuous star formation. A similar excess is not observed in field galaxies with equivalent infrared luminosities, indicating a greater fraction of the detected cluster and group members have experienced a burst of star formation in the recent past compared to their counterparts in the field. Our results suggest that gas-rich galaxies at high redshift experience a temporary increase in their star formation activity as they assemble into denser environments. Using HST ACS imaging we find that disturbed morphologies are common among the obscured starburst population and become more prevalent in regions of higher galaxy density. We conclude that mergers are the dominant triggering mechanism responsible for the enhanced star formation found in the group galaxies, while a mix of harassment and mergers are likely driving the activity of the cluster galaxies.

114.04

The Physical Conditions Of A Lensed Star-forming Galaxy At z=1.7

Jane R. Rigby¹, E. Wuyts², M. Gladders², K. Sharon², G. Becker³

¹Goddard Space Flight Center, ²University of Chicago, ³Kavli Institute for Cosmology and Institute of Astronomy, United Kingdom.

10:40 AM - 10:50 AM

Room 606

We report rest-frame optical Keck/NIRSPEC spectroscopy of the brightest lensed galaxy yet dis- covered, RCSGA 032727-132609 at z=1.7037. From precise measurements of the nebular lines, we infer a number of physical properties: redshift, extinction, star formation rate, ionization parameter, electron density, electron temperature, oxygen abundance, and N/O, Ne/O, and Ar/O abundance ratios. The limit on [O III] 4363 A tightly constrains the oxygen abundance via the "direct" or Te method, for the first time in an average-metallicity galaxy at $z\sim2$. We compare this result to several standard "bright-line" O abundance diagnostics, thereby testing these empirically-calibrated diagnostics in situ. Finally, we explore the positions of lensed and unlensed galaxies in standard diagnostic diagrams, to explore the diversity of ionization conditions and mass-metallicity ratios at z=2.

114.05D

WiFeS & GOALS: An IFU Study Of Metallicity, Shocks, And More In Nearby U/LIRGS

Jeffrey Rich¹, L. Kewley¹, M. Dopita²

¹University Of Hawaii, ²RSAA, Australian National University, Australia.

10:50 AM - 11:10 AM

Room 606

Ultraluminous/Luminous Infrared Galaxies (U/LIRGs) are an excellent laboratory for investigating galaxy formation and evolution. They are complex systems, running the gamut of galaxy nuclear types and covering a sequence of massive mergers from isolated starburst galaxies to completely coalesced mergers with post-starburst populations and strong AGN. The detailed relationship between star formation, AGN, the ISM environment, gas motions, and merger evolution in LIRGs remains poorly understood.

This talk presents the first results from a survey of nearby U/LIRGs from the GOALS sample. Our data come from WiFeS, a new IFU on the ANU 2.3m at Siding Spring Observatory. WiFeS has proved well suited for observing nearby U/LIRGs given its wide 25"x38" field of view, moderate R~7000 resolution and broad wavelength coverage (370-700 nm).

We investigate galactic winds, extended emission power sources, metallicity distributions and stellar populations in our sample of U/LIRGs, many of which are merging systems.

Our early results indicate extended LINER emission driven by slow shocks in some of our observed systems, which could have important implications for similar composite and LINER sources. We provide

new slow shock models which provide an excellent fit to the observed line ratios. I will also discuss the observations of the least IR luminous galaxy in our sample, NGC 839, which seems to be a precursor E+A galaxy.

Our work has shown that IFU data is incredibly useful for understanding key features of U/LIRGs and disentangling the composite nature of these complex systems.

114.06

The Crystalline Fraction Of Interstellar Silicates In Starburst Galaxies

Francisca Kemper¹, A. J. Markwick¹, P. M. Woods¹

¹Univ. of Manchester, United Kingdom.

11:10 AM - 11:20 AM

Room 606

We present a model using the evolution of the stellar population in a starburst galaxy to predict the crystallinity of the silicates in the interstellar medium of this galaxy. We take into account dust production in stellar ejecta, and amorphization and destruction in the interstellar medium and find that a detectable amount of crystalline silicates may be formed using relatively extreme input parameters. We discuss the effect of dust destruction and amorphisation of supernovae, and the relatively low dust-production efficiency of supernovae, and find that when taking this into account, crystallinity in the interstellar medium of Ultraluminous Infrared Galaxies have been observed (Spoon et al. 2006, ApJ 638, 759). We conclude that not all these crystalline silicates can be of stellar (e.g. starburst related) origin, and additional crystallisation must be asociated with AGN activity.

114.07

The New Chandra View of M82

K. D. Kuntz¹, D. K. Strickland¹, T. M. Heckman¹, L. Armus², R. E. Kilgard³, A. Ptak¹, T. P. Roberts⁴, R. K. Smith⁵, M. J. Ward⁴, A. Zezas⁵

¹Johns Hopkins Univ., ²California Institute of Technology, ³Wesleyen Univ., ⁴Durham University, United Kingdom, ⁵SAO.

11:20 AM - 11:30 AM

Room 606

M82 is the closest classical staruburst galaxy without a complicating AGN, showing a strong wind that extends more than 10 kpc out into the halo. As such it has been an important laboratory for studying both the sources powering the wind and the physical conditions within the wind itself. We have obtained a deep (497 ks) image of M82 with the Chandra ACIS-S which provides unprecedented detail about the wind structure within the central 5 kpc, and reveals large discontinuous emission regions at 5 and 7 kpc as well as the "cap" at 10.5 kpc (which are only partially correlated with structures seen in the UV and optical). We will present a preliminary hardness map and spatially resolved spectroscopic analysis.

115 **Evolution of Galaxies I Oral Session** Room 607

115.01D

The Impact of Ram Pressure Stripping on Virgo Cluster Spirals

Anne Abramson¹, J. D. P. Kenney¹ ¹Yale University.

10:00 AM - 10:20 AM

Room 607

In recent years, both observations and simulations have shown that ICM-ISM stripping is likely an important driver of galaxy evolution. In order to understand the impact of stripping on galaxy evolution, it is vital to determine how the multi-phase ISM behaves during stripping, how long it takes to strip a galaxy, and how stripping influences star formation. We present multi-wavelength studies of three Virgo Cluster spirals undergoing active ram pressure stripping, including two with HST imaging. We estimate timescales for various stripping-related processes in the galaxies and identify signatures of stripping in the galaxies' ISM and star formation distributions. All three have undisturbed old stellar disks and show one-sided extraplanar ISM distributions. This extraplanar ISM hosts regions of ongoing and recent star formation that has taken place within the past few hundred Myr, with some regions significantly younger. The galaxy NGC 4330 has distinct leading and trailing sides, including a striking ISM "upturn" feature at the leading edge. There are significant differences between the galaxy's optical, UV, H α , and HI morphologies, and we use stellar population models to estimate that it has taken 200-400 Myr to strip the ISM from a radius of >8 to 5 kpc on the galaxy's leading side. HST imaging reveals that NGC 4522 and NGC 4402 have GMC-mass dust clouds located outside of their main ISM truncation radii, showing that the most massive clouds can decouple from the rest of the ISM during stripping. Dust features with linear morphologies in both galaxies reveal the projected ICM wind direction. By identifying morphological characteristics related to the ram pressure stripping process, we constrain the physics of interactions between the ICM and the complex multi-phase ISM, and we provide a foundation for future observational and theoretical studies investigating the extent to which ICM-ISM interactions drive galaxy evolution.

115.02D

Growth and Evolution of the M81 Group of Galaxies **Mihoko Yukita**¹, D. Swartz² ¹Univ. of Alabama, ²USRA.

10:20 AM - 10:40 AM Room 607

The goal of this study is to investigate the cycle of the star formation focusing on the young massive star-forming regions and their interaction with their surroundings on the local scales in galaxies in the M81 group. The X-ray data are analyzed to understand the hot phase of the interstellar medium as characterized by the X-ray properties of the hot gas, separately treating supernovae remnants, Hii regions, and diffuse residual emission. The observed hot gas temperature of the events related to starforming activities do not change dramatically over the recent star-formation time scale, about 100 Myr, but the density of the hot gas and hence pressure may decrease over time. The physical properties of the star-forming events on local scales are derived by comparing the broadband spectra using GALEX and Spitzer data to the stellar population synthesis models convolved with the dust reprocessing model. The mechanical luminosity from stars via stellar winds and supernovae is estimated based on the

derived physical properties and compared to the X-ray luminosity of star-forming regions to estimate the amount of radiative losses of the hot gas. A very low ratio of the X-ray luminosity to mechanical luminosity suggests that most of the released energy goes into thermalization and is only slowly radiated over a very long period of time.

115.03

The Impact of Environment on Galaxy Group Evolution in the Coma-A1367 Supercluster Kelley M. Hess¹, E. M. Wilcots¹, M. P. Haynes², R. Giovanelli², ALFALFA Team

¹Univ. Of Wisconsin-Madison, ²Cornell University.

10:40 AM - 10:50 AM

Room 607

We present the HI content of galaxies and galaxy groups in the Coma-Abell 1367 Supercluster derived from a 180 square degree strip of the ALFALFA survey between +24d and +28d from 11h to 14h. We use this data to present a complete view of the neutral gas content in galaxy groups as a function of the large scale environment and derive a group HI mass function. The galaxy groups, derived from SDSS, span a range of global environments from the highest density sub-clumps falling into the center of the Coma cluster, to groups that make up the filament between the Coma and Abell 1367, to poor groups that exist on the edges of voids. Using the results from ALFALFA as well as widefield imaging and GALEX UV data we test the idea that the majority of galaxy evolution happens in groups prior to their in-fall into a galaxy cluster. In addition we correlate the frequency of low luminosity AGN activities with the HI properties of the environment. Together these multi-wavelength observations show how the HI content, the star formation rate and the AGN frequency change as a function of local galaxy density and distance from the cluster center and show how the role of environment affects galaxy evolution.

115.04

The Impact Of Radio-jet Driven Outflows On The Molecular Gas In Powerful Radio-galaxies

Pierre Guillard¹, P. Ogle¹, B. Emonts², R. Morganti³, P. Appleton⁴, C. Tadhunter⁵, T. Oosterloo³, A. Evans⁶ ¹Spitzer Science Center, Caltech, ²Australia Telescope National Facility, CSIRO, Australia, ³Netherlands Foundation for Research in Astronomy, Netherlands, ⁴NASA Herschel Science Center, IPAC, ⁵Department of Physics and Astronomy, University of Sheffield, United Kingdom, ⁶University of Virginia. 10:50 AM - 11:00 AM

Room 607

Observations of ionized and neutral gas outflows in radio-galaxies (RG) suggest that AGN feedback has a galaxy-scale impact on the host ISM, but it is still unclear how the molecular gas is affected. Thus it is crucial to determine the physical conditions of the molecular gas in powerful RG to understand how radio sources may regulate the star formation in their host galaxies. We present deep Spitzer IRS high-resolution spectroscopy of 8 nearby RG that show fast HI outflows. Strikingly, all of these RG have extremely bright H2 mid-IR lines that cannot be accounted for by UV or X-ray heating. This strongly suggests that the radio jet, which drives the HI outflow, is also responsible for the shock-excitation of the warm H2 gas. In addition, the warm H2 gas does not share the kinematics of the ionized/neutral gas. In most of the sources, the mid-IR H2 lines are unresolved by the IRS, whereas ionized gas lines (e.g. NeII, NeIII) have FWHM up to 1200 km/s. If the dissipation of a small fraction (<10%) of the jet kinetic energy can explain the heating of the molecular gas, our data do not show that a significant fraction of the total molecular mass is expelled from these galaxies.

115.05

Galaxy Build-up And Evolution At z>=7: Results From The Ultra-deep Wfc3/ir Observations Over The Hudf From The Hudf09 Program

Rychard Bouwens¹, HUDF09 Team

¹UC Santa Cruz / Leiden. 11:00 AM - 11:10 AM

Room 607

The new WFC3/IR camera aboard HST enables us to survey the sky in the near-IR data 40x more efficiently than ever before -- permitting us to make enormous strides in our searches for z>=7 galaxies. Already in the 15 months of observations, we have deep and ultra-deep observation over 52+ arcmin**2 over legacy fields like the HUDF and GOODS. With these data, we have been able to select 80+ z^7 galaxies, 50+ z^8 galaxies, and even a candidate z^10 galaxy. These new selections have allowed us to quantify the evolution of the UV LF and

faint-end slope from z^{10} , significantly constrain the stellar populations and dust properties of z^{7-10} galaxies, and construct a general picture of how galaxies build up early in the universe. In this presentation, I highlight a few of our results.

116

Computation: Learning, Simulating, Data Reduction Oral Session *Room 401*

116.01

Automatic QSO Selection Algorithm Using Time Series Analysis and Machine Learning

Dae-Won Kim¹, P. Protopapas¹, C. Alcock¹, Y. Byun², R. Khardon³

¹Harvard-Smithsonian Center for Astrophysics, ²Yonsei University, Korea, Republic of, ³Tufts University. 10:00 AM - 10:10 AM

Room 401

We present a new QSO selection algorithm using time series analysis and supervised machine learning. To characterize the lightcurves, we extracted multiple times series features such as period, amplitude, color and autocorrelation value. We then used Support Vector Machine (SVM), a supervised machine learning algorithm, to separate QSOs from other types of variable stars, microlensing events and non-variable stars.

In order to train the QSO SVM model, we used 58 known QSOs, 1,629 variable stars and 4,288 nonvariable stars from the MAssive Compact Halo Objects (MACHO) database. Cross-validation test shows that the model identifies 80% of known QSOs and have 25% false positive rate. Most of the false positives during the cross-validation are Be stars, known to show similar variability characteristic with QSOs.

We applied the trained QSO SVM model to the MACHO Large Magellanic Cloud (LMC) dataset, which consists of 40million lightcurves, and found 1,097 QSO candidates. We crossmatched the candidates with several astronomical catalogs including the Spizter SAGE (Surveying the Agents of a Galaxy's Evolution) LMC catalog and various X-ray catalogs. The results suggest that the most of the candidates are likely true QSOs.

116.02

Combining Eulerian and Lagrangian Schemes to Investigate Outflows from AGN and their Effect on Star-Forming Galaxies

Mark L. A. Richardson¹, E. Scannapieco¹

¹Arizona State University.

10:10 AM - 10:20 AM

Room 401

Issues with simulating astrophysical phenomenon have arisen lately with the appropriateness of the two dominant methods: Adaptive Mesh Refinement (AMR), which is well suited for mixing of media, turbulent flow, shocks, and shear layers, and Smoothed Particle Hydrodynamics (SPH), which is less complex, and more easily able to cover length scales spanning several orders of magnitude. For problems including the dynamics of stellar interactions, galactic formation, galactic feedback, and cosmological evolution, both these capabilities are essential. To address these issues, we created a tool to convert SPH datasets from codes such as SNSPH and Hydra into initial conditions for the AMR code FLASH, allowing efficient simulation of the initial conditions on large scales, and further simulation of the small scale regions of interest. As a test case we modeled colliding white dwarfs as possible SNIa progenitors to illuminate different mechanisms of Ni56 production. Our approach was then applied to cosmological datasets to allow for large-scale cosmological simulations in z = 2 galaxies. We would like to thank the Natural Sciences and Engineering Research Council of Canada for their support of this research.

116.03D

Structure Formation in the Early Universe

Andrew J. Davis¹, P. Natarajan¹ ¹Yale University. 10:20 AM - 10:40 AM

Room 401

We present results from simulations of dark matter halos at high redshifts that likely host the some of the earliest stars and galaxies in the Universe. We present measurements of the halos' angular momentum, shape, and density profile for halos from z=15 to 6. We find that high spin haloes have stronger clustering strengths, and are found preferentially in high density environments and have closer neighbors than their low spin counterparts. High redshift spherical haloes are also up to 50 per cent more clustered than extremely aspherical haloes. We also present the results of simulations including baryons at high redshift, high spin halos to study the relation between the halo and baryonic structural properties at these early times.

116.04

Improving the Background Subtraction for X-Ray Observations of Galaxy Clusters

Wenhao Liu¹, D. Buote¹, P. Humphrey¹

¹University of California, Irvine.

10:40 AM - 10:50 AM

Room 401

The use of clusters as cosmological probes requires accurate measurements of global cluster properties, such as the virial mass. Since the X-ray emission rapidly decreases with radius, characterization of the background is a critical factor limiting the accuracy of such global mass measurements. We propose a method to improve background subtraction of Chandra ACIS observations that involves detailed modeling of the background components and the use of multiple apertures that contain both cluster

emission and background. Preliminary results applying this method to a sample of nearby clusters will be presented.

116.05

MegaPipe: the MegaCam Image Stacking Pipeline Stephen Gwyn¹

¹Canadian Astronomy Data Centre, Canada. 10:50 AM - 11:00 AM

Room 401

This presentation describes the MegaPipe image processing pipeline at the Canadian Astronomical Data Centre (CADC). The pipeline takes multiple images from the MegaCam mosaic camera on CFHT and combines them into a single output image. MegaPipe takes as input detrended MegaCam images and does a careful astrometric and photometric calibration on them. The calibrated images are then resampled and combined into image stacks. MegaPipe is run on PI data by request, data from large surveys (the CFHT Legacy Survey and the Next Generation Virgo Survey) and all non-proprietary MegaCam data in the CFHT archive. The stacked images and catalogs derived from these images are available through the CADC website. Currently, 2000 square degrees have been processed.

116.06

Is the k Coefficient Constant?

Elise Weaver¹, D. Caton¹, A. B. Smith¹

¹Appalachian State University.

11:00 AM - 11:10 AM

Room 401

Stored in the archives at Appalachian State University's Dark Sky Observatory (DSO), there are approximately 30 years (starting in 1981) of variable star observations made with the observatory's 18inch telescope. These observations either come in the form of CCD images or older photomultiplier measurements of brightness. Both types of files contain brightness information on variable stars, and comparison stars. Looking at the comparison stars, we can calculate the extinction coefficient, k, by plotting how the magnitude of the star changes with airmass. The slope of the linear fit is k. Since k is the factor by which light is attenuated by the atmosphere, we hypothesize that if find any trends in k over the 30 year span of data, we can infer something about how the Earth's atmosphere has changed. We have processed observation runs during the spring and fall (the times of the year with the best viewing conditions at DSO) that occurred in the latest seven years of the telescope's operation. Additionally, the ten years of photomultiplier data has an accompanying k measurement, which was calculated along side the light curve. Using these preliminary data, we cannot see any trends, but we need to fill in this middle regime before we can draw any conclusions. The approximately 15 years of intervening data needs to be processed, but that process is slowed by the disorganization of the data, which we are currently sorting. This research is currently being funded by the North Carolina Space Grant and Appalachian State University.

116.07

Subtraction Of Point Sources From Interferometric Radio Images Through An Algebraic Forward Modeling Scheme

Gianni Bernardi¹, D. Mitchell¹, S. Ord¹, L. Greenhill¹, B. Pindor², R. Wayth³, S. Wyithe² ¹Harvard-Smithsonian Center for Astrophysics, ²University of Melbourne, School of Physics, Australia, ³ICRAR/Curtin Institute of Radioastronomy, Australia. 11:10 AM - 11:20 AM

Room 401

Cutting edge cosmological investigations of the Epoch of Reionization (EoR) are driving a renovated effort in building low frequency radio interferometers. In order to detect the tiny EoR signal, high dynamic range (DR) imaging at frequencies below 200~MHz is required.

High DR images are traditionally obtained by subtraction of bright sources from the ungridded visibilities, however, future generations of large-N radiotelescopes will generate such high volume data stream that the cost of storing the raw ungridded visibilities will be prohibitive. The DR will therefore be limited by well known pixelization effects.

Further challenges for an image based deconvolution at low frequencies are a point spread function which varies significantly across the field of view, a time and frequency variable receptor response and ionospheric variability.

In this presentation, we introduce a deconvolution algorithm which makes use of forward modeling to mitigate against the limitations of image-based deconvolution. Through forward modeling it is possible to generate a spatially variable point spread function and relate the sky brightness distribution to astrophysical parameters which are then retrieved through a non linear least squares minimization. We applied the method to the deconvolution of point sources on simulated observations of the Murchison Wide-field Array (MWA). MWA is the array with the largest number of correlated elements currently under construction (512 final elements) and will not have the option of storing the raw visibility data over long time integrations.

We find that the accuracy to which point sources can be deconvolved/subtracted is only limited by their signal to noise ratio, not by their number or positions, therefore the DR increases with integration time. These results indicate this method to be promising for applications that require high DR imaging, like the detection of the EoR signal.

This work was supported by the U.S. National Science Foundation.

116.08

Automatic Recommendation of Astronomy Literature

Edwin A. Henneken¹, M. J. Kurtz¹, A. Accomazzi¹, C. S. Grant¹, D. Thompson¹, E. Bohlen¹, G. Di Milia¹, J. Luker¹, S. S. Murray¹

¹Smithsonian Astrophysical Observatory.

11:20 AM - 11:30 AM

Room 401

Authors publish because they want to transfer information. An essential ingredient for this transfer is being able to find this information. As the Literature Universe is expanding rapidly, finding your way in this deluge of information can be a daunting task. How do you find what you are looking for in a reasonable amount of time and more importantly, information you could not have found using the normal information discovery model? When you have some prior information (like author names and/or subject keywords), you can use your favorite search engine and apply that information as filters. There are also more sophisticated services like the myADS service of the SAO/NASA Astrophysics Data System (ADS), that do intelligent filtering for you and provide you with customized suggestions. Alternatively, you can ask somebody you consider to be an expert. On this poster we describe a method (the "recommender system") that mimics this information "ask the export" discovery model, argue that it is practically feasible to incorporate this method as a useful addition to the existing ADS service and show that it is able to produce meaningful results. The ADS is funded by NASA Grant NNX09AB39G.

Monday, January 10, 2011, 11:40 AM - 12:30 PM

117 *Chandra's First Decade (Plus) of Discovery* Invited Session *Ballroom 6AB*

117.01 Chandra's First Decade (Plus) of Discovery Harvey Tananbaum¹

¹Harvard-Smithsonian, CfA. Ballroom 6AB

NASA's Chandra X-ray Observatory has provided an unprecedented view of the Universe at x-ray wavelengths since its launch in July 1999. Chandra's spectacular images and detailed spectra of astrophysical systems ranging from solar system objects to distant galaxies and clusters shed (x-ray) light on diverse topics such as stellar formation and demise, black hole-galaxy-cluster interactions, and properties of dark matter and dark energy. After a brief overview and status report on the Observatory, the focus of the talk will be on selected scientific highlights with emphasis on recent Chandra results.

Monday, January 10, 2011, 2:00 PM - 3:30 PM

121

Super-Earths and Terrestrial Planets: Latest Results from the Kepler Mission Special Session Ballroom 6C

121.01

Kepler Mission Overview

William J. Borucki¹, D. G. Koch¹, T. N. Gautier, III², E. W. Dunham³, Kepler Science Team
¹NASA Ames Research Center, ²Jet Propulsion Laboratory, ³Lowell Observatory.
2:00 PM - 2:30 PM
Ballroom 6C
Early Kepler observations show the presence of over 750 candidate planets, 1800 eclipsing binary stars, and variable stars of american variable stars of american variable stars.

and variable stars of amazing variety. Many of the planetary candidates are smaller than Neptune. Discoveries of seven new exoplanets are shown including one of with two confirmed transiting planets. The candidate- and the announced-planets are compared with known exoplanets with respect to mass, size, density, and orbital period.

Support by the NASA Astrophysics Division is gratefully acknowledged.

121.02

Physical Properties of Kepler's Super-Earths

Dimitar D. Sasselov¹, Kepler Science Team

¹Harvard-Smithsonian CfA.

2:30 PM - 2:45 PM

Ballroom 6C

Planets in the radius range from about 1.25 to 2 Re, referred to as Super-Earth-sized planets, do not exist in our Solar System. Their physical properties as determined by theoretical modeling are expected to differ in many ways from our Solar System experience. The Kepler Mission is going to discover many such planets and determine their orbits and radii. For some of them follow-up observations may determine masses, and for a few of them asteroseismology of their stars from the Kepler light curve may

determine an age. I will discuss theoretical models for such planets and how they could be constrained by the anticipated Kepler Mission observations.

121.03

Transit Timing Variations of Kepler Planets

Matthew J. Holman¹, D. C. Fabrycky¹, D. Ragozzine¹, E. B. Ford², J. H. Steffen³, W. F. Welsh⁴, J. J. Lissauer⁵, Kepler Science Team

¹Harvard-Smithsonian, CfA, ²University of Florida, ³Fermilab Center for Particle Astrophysics, ⁴San Diego State University, ⁵NASA Ames Research Center.

2:45 PM - 3:00 PM

Ballroom 6C

For a transiting planet following a fixed Keplerian ellipse, observers would measure a constant interval between successive transits. Orbital precession induced by general relativity, a planetary tidal bulge, or stellar oblateness could result in a variation of the transit interval for a planet with an eccentric or inclined orbit. Furthermore, tidal dissipation should alter the orbital period of the planet. These slow effects can only be detected over several years. However, the gravitational influence of other planets in the system can yield a detectable change in the transit interval over much shorter time scales. With the precision and continuous monitoring provided by Kepler photometry, the presence of sub-Earth mass planets in resonance, as well as larger planets at a wide range of orbital periods could, in principle, be readily detected. With the detection of transit timing variations in systems with multiple transiting bodies, such as Kepler-9, it is possible to establish from the transit observations alone that these bodies have planetary masses. But the combination of Kepler photometry with high-precision radial velocity observations is particularly powerful in establishing the orbital and physical properties of such systems. We will present the results of the analyses of transit timing variations in exoplanet systems observed by Kepler to date.

Kepler was selected as the 10th mission of the Discovery Program. Funding for this mission is provided by NASA, Science Mission Directorate.

121.04

The Kepler Asteroseismic Investigation Hans Kieldsen¹

¹University of Aarhus, Denmark.

3:00 PM - 3:15 PM

Ballroom 6C

The aim of asteroseismology is to probe the interiors of stars and quantify their properties, such as radius, mass, rotation and age, through observations of oscillation modes. Using the ultrahigh photometric precision and the extended length of the time series from Kepler one can perform asteroseismology which is orders of magnitudes more accurate than one could do just a few years ago. The Kepler asteroseismic programme is being conducted through the Kepler Asteroseismic Science Consortium (KASC), whose 400 members are organized into 13 working groups (KASC WGs) by type of variable star. The KASC WGs are established to ensure an efficient and structured work within KASC focusing on data analysis, stellar modelling and publication of data. The goals of the asteroseismic part of the Kepler project are to perform detailed studies of stellar interiors and to support the exoplanet investigation by measuring accurate stellar properties, especially the radius of planet host stars. The first results of the asteroseismic analysis indicate how the future analysis of Kepler data for many types of stars will impact our general understanding of stellar structure and evolution. A series of the most fascinating results from the asteroseismic analysis of Kepler data will be presented.

121.05

Stellar and Galactic Astrophysics with Kepler: Results from the Guest Observer Program Michael N. Fanelli $^{\rm 1}$

¹NASA Ames Research Center. 3:15 PM - 3:30 PM Ballroom 6C

Kepler was launched in March, 2009 with a primary mission of determining the statistics of Earth-sized planets in the habitable zones of Sun-like stars. Each quarter Kepler continuously observes on order ~160,000 stars at a 30 minute cadence, and 500 stars at a 1-minute cadence. These light curves define a unique dataset for astrophysics, beyond the primary exoplanet mission. A broad range of topics are addressed, including stellar parameters from eclipsing binary modeling, asteroseismology, stellar activity cycles and pulsation modes across the HR diagram, episodic variability such as flares and accretion physics, and variability in galactic nuclei. In this talk, we will present a sampling of results derived from the Kepler data, selected to represent the efforts of Guest Observers and the general astronomical community. As the Kepler program proceeds, the growing archive of precision light curves will provide unparalled opportunities to explore many puzzles in the field of time domain astronomy.

122

Community Science with LSST Special Session *Ballroom 6A*

122.01 **LSST System Overview Donald Sweeney**¹ ¹*LSSTC.* 2:00 PM - 2:15 PM *Ballroom 6A*

The Large Synoptic Survey Telescope Corporation was formed to design, build, and operate the LSST. Currently 34 institutions have joined. The proposed observatory is funded as a private/federal partnership with federal support from the NSF and DOE. The LSST has a guiding principle of open-data and open-source for everyone in the US and Chile without any proprietary period. The total cost of the LSST Observatory in 2010 USD is approximately 465 million. Full science operations will begin six years after federal construction funding begins.

The LSST will be located on Cerro Pachón Ridge near Gemini-South and SOAR. The telescope will survey the entire available sky every few nights using six bands 350nm to 1100nm *ugrizy*, covering 20,000 square degrees deeply in all six filters 1000 times in ten years. The optical design has an effective collecting aperture of 6.5 meters and a field of view of 9.6 square degrees.

Currently, all three of the large mirrors are in construction using private funding. The site architecture and site preparation are in process. All Chilean environmental studies are approved and permits awarded. The 3.2 GigaPixel camera is the primary deliverable of the DOE under the leadership of SLAC. Prototype sensors have been delivered from two commercial suppliers. The Observatory will produce 18TB of data each night. Over the planned ten year survey the survey will produce 100PB of data and catalogs that will be processed and stored at NCSA. Transient events will be announced within 60 seconds world-wide; Static sky catalogs will be updated on various time scales; Data Releases with full provenance will occur once a year and include reprocessing of all prior data. Data Access Centers will be strategically located for serving the data to the scientific community and the general public.

122.02 LSST Science Collaborations Michael A. Strauss¹

¹Princeton Univ.. 2:15 PM - 2:30 PM Ballroom 6A

The LSST will have enormous scientific impact on areas ranging from Earth-crossing asteroids to the most distant quasars, from the structure of the Milky Way halo to the distribution of dark matter on the largest scales and the nature of dark energy. To maximize the scientific potential of the survey, we have formed 11 so-called "Science Collaborations," with membership from LSST member institutions and the broader scientific community, which are preparing the tools needed to carry out their science once LSST data start to flow. They also represent advocates for their science areas, giving input to decisions about filter design, survey cadence, image processing algorithms, and database structure. Finally, they are playing a key role in testing the LSST software, and in planning for commissioning the telescope and system. Outside LSST member institutions, membership in the science collaborations is via application; there is a annual call for applications from the astronomy and physics community administered by NOAO. There is also the opportunity to propose new science collaborations.

122.03 Galactic Science With LSST Beth Willman¹

¹Haverford College. 2:30 PM - 2:45 PM Ballroom 6A

LSST will yield revolutionary, multi-dimensional maps of the Milky Way (MW) galaxy and its neighbors. Over its 10-year survey period, LSST will catalog 10 billion MW stars (including photometric metallicities for 200 million F/G stars within 100 kpc) and map their tangential velocity field to at least 10 kpc (at 10 km/s precision) and as far as 25 kpc (at 60 km/s precision). Parallax data will allow a complete census of stars above the hydrogen-burning limit that are closer than 500 pc, and RR Lyrae stars will be detectable through their variability to a distance limit of 400 kpc. The star formation and hierarchical merging history of the MW to be facilitated by these deep maps will complement LSST's observational cosmology based on billions of distant galaxies. The census of MW dwarf galaxy satellites and remnants will be complete out to the virial radius within LSST's footprint, and will provide a detailed window into the spatial distribution and abundance of dark matter halos on sub-galactic scales. In this talk, I will highlight a few specific Galactic science programs and the corresponding simulations and observations we are conducting to prepare for LSST operations.

122.04

Extragalactic Science with LSST Philip J. Marshall¹

¹Stanford University. 2:45 PM - 3:00 PM Ballroom 6A

The LSST survey will provide a very deep mine of data on the extra-galactic universe. The system is designed to enable all four of the probes identified by the Dark Energy task force, measuring cosmological parameters through cataloging 4 billion galaxies in photometric redshift bins for Baryon

Acoustic Oscillation measurements, discovering hundreds of thousands of massive galaxy clusters, providing good lightcurves for hundreds of thousands of type Ia supernovae, and mapping the large scale dark matter distribution across half the sky and 10 billion years of cosmic growth with weak gravitational lensing. The high statistical precision will allow us to look for spatial variations in the universal expansion, while the combination and cross-correlation of these measurements will allow us to explore generalized parametrizations of dark energy, and test for non-standard gravity as analternative. The survey data will also allow other cosmological tests, such as cosmography with the thousands of expected strong gravitational lenses. Moreover, the study of galaxies to low surface brightness levels, the supermassive black holes active in their nuclei, and the supernovae they host will be greatly expanded by the enormous samples of objects and images generated. The scale of each of these science projects will require us to think of new ways of exploring and handling such large datasets.

122.05

Transient and Variable Star Science with LSST

Lucianne M. Walkowicz¹, LSST Transients and Variable Stars Science Collaboration

¹UC Berkeley. 3:00 PM - 3:15 PM Ballroom 6A

The time resolution and high etendue of LSST will revolutionize studies of a wide variety of astrophysical phenomena. The umbrella of time domain science with LSST encompasses objects both familiar and exotic, from classical variables within our Galaxy to explosive cosmological events. Within our Galaxy, LSST observations of variable stars will allow the mapping of the stellar halo in new detail, determination of the global Galactic cool star flare rate, and detection of rare evolved binary populations. Beyond the Milky Way, LSST will probe the distant Universe for the most luminous events. LSST will make localization for gravity wave events possible, identify counterparts to GRBs and X-ray flashes, and discover new supernovae. Increased sample sizes of known-but-rare observational phenomena will quantify their distributions for the first time, thus challenging existing theory. Perhaps most excitingly, LSST will provide the opportunity to sample previously untouched regions of parameter space, where transient events are expected on theoretical grounds, but have not yet been observed. In this talk, I will highlight some of the interesting scientific possibilities LSST will bring to transient and variable star science, as well as the challenges we face and opportunities for community involvement.

122.06

LSST Resources for the Community

R. Lynne Jones¹

¹Univ. of Washington.

3:15 PM - 3:30 PM

Ballroom 6A

LSST will generate ~100 petabytes of images and ~20 petabytes of catalogs, covering 18,000-20,000 square degrees of area sampled every few days, throughout a total of ten years of time -- all publicly available and exquisitely calibrated.

The primary access to this data will be through Data Access Centers (DACs). DACs will provide access to catalogs of sources (single detections from individual images) and objects (associations of sources from multiple images). Simple user interfaces or direct SQL queries at the DAC can return user-specified portions of data from catalogs or images. More complex manipulations of the data, such as calculating multi-point correlation functions or creating alternative photo-z measurements on terabyte-scale data, can be completed with the DAC's own resources. Even more data-intensive computations requiring access to large numbers of image pixels on petabyte-scale could also be conducted at the DAC, using

compute resources allocated in a similar manner to a TAC. DAC resources will be available to all individuals in member countries or institutes and LSST science collaborations. DACs will also assist investigators with requests for allocations at national facilities such as the Petascale Computing Facility, TeraGrid, and Open Science Grid.

Using data on this scale requires new approaches to accessibility and analysis which are being developed through interactions with the LSST Science Collaborations. We are producing simulated images (as might be acquired by LSST) based on models of the universe and generating catalogs from these images (as well as from the base model) using the LSST data management framework in a series of data challenges. The resulting images and catalogs are being made available to the science collaborations to verify the algorithms and develop user interfaces.

All LSST software is open source and available online, including preliminary catalog formats. We encourage feedback from the community.

123 *Science Highlights from NASA's Astrophysics Data Analysis Program I* Special Session *Ballroom 6B*

123.01

Overview and Status of NASA's ADAP Douglas M. Hudgins¹

¹NASA Headquarters. 2:00 PM - 2:15 PM Ballroom 6B

Over the years, NASA has invested heavily in the development and execution of an extensive array of space astrophysics missions. The magnitude and scope of the archival data from those missions enables science that transcends traditional wavelength regimes and allows researchers to answer questions that would be difficult, if not impossible, to address through an individual observing program. To capitalize on this invaluable asset and enhance the scientific return on NASA mission investments, the Astrophysics Data Analysis Program (ADAP) provides support for investigations whose focus is on the analysis of archival data from NASA space astrophysics missions. In this introduction to the scientific session, I will provide a brief introduction to the ADAP including an overview of its scope and content, as well as a synopsis of its current status and funding trajectory in coming years.

123.02

The Abundances of Carbon and Nitrogen in the Photospheres of Active B Stars Geraldine J. \mbox{Peters}^1

¹Univ. of Southern California. 2:15 PM - 2:30 PM

Ballroom 6B

Contemporary models for the structure and evolution of rapidly-rotating OB stars predict a photospheric enrichment of nitrogen due to the mixing of the CNO-processed material from the star's core with the original surface material. The predicted N-enhancement increases as the star approaches its critical rotational velocity. Alternatively the Algol primaries should have N-enriched photospheres if the material currently being transferred is from the mass loser's original core. To test these predictions, the C and N abundances in selected early Be stars and B-type mass gainers in Algol systems have been determined from spectroscopic data obtained with the *IUE* and *FUSE* spacecraft. The abundance analyses, carried through with the Hubeny/Lanz NLTE codes TLUSTY/SYNSPEC, were confronted with some challenges that are not encountered in abundance studies of sharp-lined, non-emission B stars

including the treatment of shallow, blended rotationally-broadened lines, the appropriate value for the microturbulence parameter, correction for disk emission and possible shell absorption, and latitudinal variation of Teff and log g. The FUV offers an advantage over the optical region as there is far less influence from disk emission and the N lines are intrinsically stronger. Particularly useful are the features of C II 1324 Å, C III 1176 Å, 1247 Å, N I 1243 Å, and N III 1183,84 Å. Be stars with *v* sin *i* < 150 km s⁻¹ were chosen to minimize the effect of latitudinal parameter variation. Given the errors it appears that the N abundance in the Be stars is normal. Expected mixing is apparently suppressed, and this study lends no support for Be star models based upon critical rotation. However, expected N-enhancement and a low C abundance are inferred for the B-type primaries in some interacting binaries.

GJP is grateful for support from NASA Grants NNX07AH56G (ADP) and NNX07AF89G (FUSE), and the USC WiSE program.

123.03

Analysis of Archival FUSE Spectra of Accreting White Dwarfs in Cataclysmic Variables Patrick \mathbf{Godon}^1

¹Villanova University. 2:30 PM - 2:45 PM

Ballroom 6B

We study the accreting white dwarfs (WDs) and accretion disks in Cataclysmic Variables (CVs) by carrying out a systematic analysis of the FUSE spectra of galactic CVs. Using the codes TLUSTY, SYNSPEC and BINSYSN, we generate synthetic spectra of WDs, and accretion disks, and derive the parameters of the systems: the temperature of the WD, its gravity, projected rotational velocity, chemical aundances, and the mass accretion rate. We use these results to probe the evolution of CVs and accretion physics. Our findings confirm that gravitational radiation can account for the WD effective temperature of polars both above and below the gap. Above the gap, the majority of DNs have a temperature lower than expected by the standard theory, and NL VY systems have a temperature higher than expected from the standard theory. Overall, it seems that the standard model does not agree with the nonmagnetic CVs above the period gap. A higher than expected temperature for the NL VY could be accounted for with a higher mass accretion rate.

For disk-dominated systems, we find that the basic standard disk model fails almost systematically to fit the data. We find that the disk model must be improved at high accretion rate to include the star-disk boundary layer.

As a scientific byproduct of this research we also create a web-based catalog of all the (fully reduced and co-added) FUSE spectra of CVs, including also all the synthetic spectra. This catalog will enable the full exploitation of the tremendous potential of the FUSE data for CVs on a large scale. This will be of invaluable importance for future NASA FUV space missions and it will add much value to the NASA FUSE mission itself.

This work is supported by NASA under grant NNX08AJ39G issued though the Office of Astrophysics Data Analysis Program.

123.04

Spin Measurements for a Sample of Eight Stellar-Mass Black Holes Jeffrey E. McClintock¹ *¹Harvard-Smithsonian, CfA.*

2:45 PM - 3:00 PM Ballroom 6B

Our team has published the spins of six accreting black holes, and I will present our results for two others, XTE J1550-564 and Cygnus X-1. I will discuss the implications of our spin data for models of

relativistic jets and black hole formation. We measure spin by fitting the thermal continuum X-ray spectrum of the black hole to the relativistic thin-disk model of Novikov and Thorne, thereby determining the radius of the inner edge of the disk. We identify this disk radius with the black hole's innermost stable circular orbit (ISCO). It is then trivial to deduce the spin, which for a black hole of known mass depends solely on the radius of the ISCO via a standard GR formula. Strong theoretical evidence that the thin accretion disks we study are sharply truncated at the ISCO is provided by our GRMHD simulations. Likewise, strong empirical support for identifying the disk radius we measure with the radius of the ISCO is provided by decades of observational evidence, including our recent and compelling study of LMC X-3. We find for this persistent source, based on an analysis of hundreds of spectra collected over a span of 26 years by eight X-ray satellites, that the inner radius of the accretion disk is stable to approximately 4 percent. Thus, our measurements of spin are supported by both observational and theoretical evidence.

123.05

Black Hole X-ray Sources in Extragalactic Globular Clusters Stephen E. Zepf¹

¹*Michigan State Univ..* 3:00 PM - 3:15 PM *Ballroom 6B*

Whether there are black holes in globular clusters and what the properties of any such black holes might be remained unclear for many years. Advances in both X-ray and optical/near-infrared work have enabled searches for black hole X-ray sources to be extended to extragalactic globular clusters. We combined X-ray and optical observations to identify the first unambiguous black hole in a globular cluster in 2007. Through ADP supported work we have shown that this black hole is very likely to be a stellar mass and not an intermediate mass black hole. We have also used ADP supported archival studies and pointed observations to find two more globular cluster black hole X-ray sources, and two additional objects have been reported in the literature. We discuss these discoveries and their implications for the masses of black holes in globular clusters and for the formation of accreting black hole systems in dense stellar environments.

123.06

Constraining Accreting Binary Populations in Normal Galaxies

Bret Lehmer¹, A. Hornschemeier², A. Basu-Zych², T. Fragos³, L. Jenkins², V. Kalogera³, A. Ptak², P. Tzanavaris², A. Zezas⁴

¹Johns Hopkins University, ²Goddard Space Flight Center, ³Northwestern, ⁴SAO.

3:15 PM - 3:30 PM

Ballroom 6B

X-ray emission from accreting binary systems (X-ray binaries) uniquely probe the binary phase of stellar evolution and the formation of compact objects such as neutron stars and black holes. A detailed understanding of X-ray binary systems is needed to provide physical insight into the formation and evolution of the stars involved, as well as the demographics of interesting binary remnants, such as millisecond pulsars and gravitational wave sources. Our program makes wide use of Chandra observations and complementary multiwavelength data sets (through, e.g., the Spitzer Infrared Nearby Galaxies Survey [SINGS] and the Great Observatories Origins Deep Survey [GOODS]), as well as supercomputing facilities, to provide: (1) improved calibrations for correlations between X-ray binary emission and physical properties (e.g., star-formation rate and stellar mass) for galaxies in the local Universe; (2) new physical constraints on accreting binary processes (e.g., common-envelope phase and mass transfer) through the fitting of X-ray binary synthesis models to observed local galaxy X-ray binary luminosity functions; (3) observational and model constraints on the X-ray evolution of normal galaxies over the last 90% of cosmic history (since z ~ 4) from the Chandra Deep Field surveys and accreting binary synthesis models; and (4) predictions for deeper observations from forthcoming generations of X-ray telesopes (e.g., IXO, WFXT, and Gen-X) to provide a science driver for these missions. In this talk, we highlight the details of our program and discuss recent results.

124

The Low-Frequency Gravitational Wave Universe: Detection Prospects, Sources, and Astrophysics Special Session *Room 611/612*

124.01

Low-Frequency Gravitational Wave Detection Using Radio Pulsars: Building a Galactic Scale Gravitational Wave Observatory

Fredrick Jenet¹

¹Univ. of Texas at Brownsville.

2:00 PM - 2:20 PM

Room 611/612

Observations of radio pulsars give us unique access to the nano-Hertz regime of the gravitational wave spectrum. This new window to the cosmos will allow us to study some of the most energetic events in the universe including the collision of two supermassive black holes. In this talk, we will review the basic detection techniques and discuss possible gravitational wave sources that may be detectable in the near future. We will also discuss the status of current pulsar timing based gravitational wave detection efforts.

124.02

Radio Pulsars as Gravitational Wave Detectors: Recent Observational Results Paul Demorest $^{\!\!\!1}$

¹National Radio Astronomy Observatory. 2:20 PM - 2:40 PM

Room 611/612

The idea of using an array of millisecond radio pulsars as a nanohertz-frequency gravitational wave detector has continued to attract increasing attention over the past several years. Current experimental sensitivities are beginning to probe the upper limits of the predicted signal strength and a detection seems entirely within reach. The North American Nanohertz Observatory for Gravitational Waves (NANOGrav) project has been regularly timing a set of 20 millisecond pulsars over the past 5 years. These observations use the two largest radio telescopes on Earth, Arecibo Observatory and the NRAO Green Bank Telescope. In this talk, I will present newly developed analysis procedures and timing results from the NANOGrav 5-year data set. These are then used to place a new experimental limit on the strength of the stochastic nHz-frequency gravitational wave background.

124.03

Prospects for Gravitational Wave Detection with Pulsar Timing Arrays Alberto Sesana¹

¹*Albert Einstein Institute, Germany.* 2:40 PM - 3:00 PM

Room 611/612

In the next decade the detection of gravitational waves (GW) will (hopefully) be a reality, opening a completely new window on the Universe. Massive black holes (MBH) binaries (MBHBs) are expected to be among the primary actors on this upcoming stage. Utilizing detailed MBHB population models (based on our current best understanding of galaxy formation and evolution trough mergers, and on our knowledge of the relations between MBHs and their hosts), I describe prospects of detecting GWs with forthcoming pulsar timing arrays (PTAs). A strong GW background, detectable at a level of 10-100ns timing precision, is a robust predictions of all the models. Single bright sources may also be resolvable, providing unique information about MBHB dynamics, and the physics of the processes driving their final coalescence.

124.04

Searching for Gravitational Waves with the EPTA and LEAP

Ben Stappers¹, M. Kramer²

¹University of Manchester, United Kingdom, ²Max Planck Institut fur Radioastronomie, Germany. 3:00 PM - 3:20 PM

Room 611/612

The European Pulsar Timing Array (EPTA) is a European effort spanning multiple institutes and multiple telescopes to directly detect gravitational waves by using high-precision pulsar timing. The project, instruments and its members are outlined, and methods and goals are discussed. The results of a the first EPTA upper limit on the stochastic gravitational wave background will be reported. The Large European Array for Pulsars (LEAP) will be introduced. LEAP is a project to coherently combine the signals of the large telescopes in Europe into a tied-array and increase the sensitivity, to that of a 200 m dish, for pulsars and thereby increase the precision of pulsar timing. I will present results from the initial combinations of data and discuss the prospects for the future. The LEAP project is funded through an European Research Council Advanced Grant to Michael Kramer.

125

AGN, QSO, Blazars II Oral Session Room 618/620

125.01

The Hard X-ray Spectra of Swift-BAT AGN Wayne H. Baumgartner¹, R. Mushotzky², J. Tueller³ ¹*UMBC & NASA/GSFC*, ²*UMCP*, ³*NASA/GSFC*. 2:00 PM - 2:10 PM *Room 618/620* We present a composite analysis of the hard X-ray (

We present a composite analysis of the hard X-ray (15 -- 195 keV) spectra of over 500 AGN from the Swift-BAT all sky survey. The AGN observed in over 65 months of the survey are a mixture of Seyfert galaxies (Type I 56%, Type II 43%) with a median redshift of z=0.04, and QSOs and blazars at higher redshifts.

It has been shown in high resolution X-ray (1-10 keV) studies of the cosmic X-ray background that the CXB is composed of the combined output of AGN out to high redshifts. The spectrum of the CXB is well measured and peaks in the hard X-ray band. However, the hard X-ray spectra of individual AGN have not been measured at the same level of detail until now.

We present the hard X-ray spectra of individual Type I, Type II, and Compton-thick AGN from the Swift-BAT survey as well as an analysis of the stacked spectra of these groups in order to investigate whether the spectral properties (spectral index, cutoff) vary as a class or as a function of luminosity. We then attempt to address the question of how well the hard X-ray spectrum of the CXB can be explained as a composite of the spectra of AGN in the local universe as measured by Swift-BAT.

125.02

Fermi View of the Swift/BAT Seyferts

Stacy H. Teng¹, R. M. Sambruna², D. S. Davis³, R. F. Mushotzky¹, C. S. Reynolds¹

¹Univ. of Maryland, ²NASA-HQ, ³NASA-GSFC.

2:10 PM - 2:20 PM

Room 618/620

We present the results of our detailed analysis of the first two years of Fermi data on the entire sample of Swift/BAT Seyfert galaxies. Of the 490 objects in the 58-month BAT catalog, three Seyferts have been identified to have Fermi/LAT counterparts. These objects have similar characteristics as flat-spectrum radio quasars, but are borderline radio quiet AGNs. The discovery of gamma-ray emission from Seyfert galaxies represents a new class of objects detectable by Fermi and has the potential to alter our understanding of the accretion process by the central engine. We will discuss the mechanisms for gamma-ray emission in Seyfert galaxies. Using upper limits derived from the Fermi non-detections, we will also examine the implications of these results for the GeV background. This work has been supported by the Fermi General Observers program.

125.03D

Studying The Spectral Shape And The X-ray/uv Variability Of Active Galactic Nuclei With Data From Swift And Xmm Archives

Sara Turriziani¹

¹Universita' Degli Studi Di Roma Tor Vergata, Italy. 2:20 PM - 2:40 PM Room 618/620

Many efforts have been made in understanding the underlying origin of variability in Active Galactic Nuclei (AGN), but at present they could give still no conclusive answers. Since a deeper knowledge of variability will enable to understand better the accretion process onto supermassive black holes, I built the first ensemble struction function analysis of the X-ray variability of samples of quasars with data from Swift and XMM-Newton archives in order to study the average properties of their variability. Moreover, it is known that UV and X-ray luminosities of quasars are correlated and recent studies quantified this relation across 5 orders of magnitude. In this context, I presents results on the X-ray/UV

ratio from simultaneous observations in UV and X-ray bands of a sample of quasars with data from XMM-Newton archive.

Lastly, I will present a complete sample of Swift/SDSS faint blazars and other non-thermal dominated AGNs. I used this sample to calculate the general statistical properties of faint blazars and radio galaxies and in particular their Radio LogN-LogS with fluxes down to 10 mJy, in order to gain knowledge on the contribution to Cosmic Microwave Background (CMB) and gamma-ray background radiation from the faint tail of the radio population.

I acknowledge financial support through Grant ASI I/088/06/0.

125.04D

Quasar SEDs in XMM-COSMOS: 90% Uniform, 10% Hot-Dust-Poor - Low Covering Factors and Large Accretion Disk Outer Radii

Heng Hao¹, M. Elvis², F. Civano², COSMOS Team ¹*Harvard Univ.,* ²*Center for Astrophysics.* 2:40 PM - 3:00 PM

Room 618/620

The spectral energy distributions (SEDs) of AGNs are essential to understand the physics of the supermassive black holes (SMBHs) and their host galaxies. We present a detailed study of AGN SED shapes in the optical-near infrared for 408 X-ray selected type 1 AGNs from the XMM-COSMOS Survey. We define an near-IR/optical index-index ('color-color') diagram to investigate the mixture of AGN continuum, reddening and host galaxy contribution.

We found that ~90% of the AGNs lie on mixing curves between the Elvis et al. (1994) mean AGN SED (E94) and a host galaxy, with only the modest reddening [E(B-V)=0.1-0.2]. Lower luminosity and Eddington ratio objects have more host galaxy. The E94 is remarkably good in describing the SED shape in the 0.3-3 micron decade over a range of 3.2 dex in Lopt, 2.7 dex in L/L_{Edd}, and for redshifts up to 3. However, 10% of the AGNs are inconsistent with any AGN+host+reddening mix. These AGNs have weak or non-exist near-IR bumps, suggesting a lack of the hot dust characteristic of AGNs. The fraction of these "hot-dust-poor" AGNs evolves with redshift from 6% at z<2 to 20% at 2<z <3.5. A similar fraction of HDP quasars are found in the E94 (BQS) and Richards et al. 2006 (SDSS) samples.

The 1-3micron emission is a factor 2-4 smaller than the typical E94 AGN SED. The implied 'torus' covering factor is 2%-29%, well below the 75% required by unified models. The weak hot dust emission seems to expose an extension of the accretion disk continuum in some of AGNs. We estimate the outer edge of their accretion disks to lie at ~ 10^4 Schwarzschild radii, more than ten times the gravitational stability radii. These 'hot-dust-poor' quasars may have 'tori' disrupted by mergers or may be recoiling black holes.

125.05

Chandra Observations Of The Group Gas Around 3C 449

Dharam V. Lal¹, R. P. Kraft¹, W. R. Forman¹, C. Jones-Forman¹, M. J. Hardcastle², P. E. J. Nulsen¹, J. H. Croston³

¹Harvard-Smithsonian Center for Astrophysics, ²University of Hertfordshire, United Kingdom, ³University of Southampton, United Kingdom.

3:00 PM - 3:10 PM

Room 618/620

Chandra has detected shocks in the ICM around several radio galaxies in both rich environments and relatively poor environments, but we are still far from a complete understanding of role that supersonic lobe inflation plays in the overall energy budget of the hot gas of groups and clusters of galaxies. Energy input by strong shocks may be particularly important in the thermodynamic evolution of groups, however. We present preliminary results from a deep Chandra observations of 3C 449, a canonical FR I radio galaxy, to study a large scale, high Mach number shock in a nearby (z=0.017) 1.5 keV group. We find multiple surface brightness discontinuities in the gas, probably shocks, which are indicative of the supersonic inflation of the radio lobes. We also find X-ray cavities in the group gas coincident with the radio lobes. Surprisingly, there is no X-ray synchrotron emission associated with the inner jet at flux levels well below that observed in other nearby FRIs.

125.06

Simulations Of 3D MHD Jets: The Effects Of ICM Weather And AGN History On X-ray Cavities Peter Mendygral¹, T. W. Jones¹, K. Dolag²

¹University of Minnesota, ²Max Planck Institute for Astrophysics, Germany. 3:10 PM - 3:20 PM Room 618/620 The powerful jets from AGN produce low density bubbles in the ICM of the host galaxy cluster that are

observed as X-ray cavities. The morphology of X-ray cavities is influenced by factors such as AGN history

and ICM weather. We present 3D magnetohydrodynamical (MHD) simulations of hypersonic AGN jets in realistic cluster environments that explore the relationship between these factors and cavity properties. We will also discuss the consequences on observations of X-ray cavities with synthetic observations of these simulations. This work is supported by the NSF and by the University of Minnesota Supercomputing Institute.

125.07

Extending the ChaMP/SDSS Field AGN Fraction

Daryl Haggard¹, S. F. Anderson², P. J. Green³, A. Constantin⁴, T. Aldcroft³, D. Kim³, W. Barkhouse⁵ ¹Northwestern University/CIERA, ²University of Washington, ³Harvard-Smithsonian Center for Astrophysics, ⁴James Madison University, ⁵University of North Dakota. 3:20 PM - 3:30 PM

Room 618/620

The most reliable signature of accretion in active galaxies is strong X-ray emission. To study the field AGN fraction to z = 0.7, we employ >100,000 SDSS galaxies and ~1,600 Chandra X-ray detections from the Chandra Multiwavelength Project (ChaMP). ChaMP volume completeness maps allow us to investigate the AGN fraction as a function of host galaxy properties, including absolute magnitude, X-ray luminosity, redshift, and color/morphological type, for samples complete in redshift and i-band magnitude (Mi). Conservatively defining AGN via log Lx(0.5-8keV) > 42, and weighting by the optical luminosity function (OLF) for galaxies, we find that about 1 in 150 galaxies with -18 > Mi > -26 host an active nucleus. At low redshift (z < 0.4), for bins comparable to previous cluster studies, we find no significant difference between the field and cluster AGN fractions. We use the OLF-weighted AGN fraction to compare these environments out to z ~ 1.

126

White Dwarfs in Binaries and Interacting Systems Oral Session *Room 615/617*

126.01D

Discovery of the Eclipsing Detached Double White Dwarf Binary NLTT 11748

Justin D. R. Steinfadt¹, D. L. Kaplan², A. Shporer¹, L. Bildsten¹, S. B. Howell³ ¹UCSB, ²University of Wisconsin - Milwaukee, ³NOAO.

2:00 PM - 2:20 PM

Room 615/617

We report the discovery of the first eclipsing detached double white dwarf (WD) binary, NLTT 11748. In a photometric search for pulsations from this low-mass helium core WD, we discovered approx 180 s 3%--6% dips in the photometry. Subsequent radial velocity measurements found variations with a semiamplitude K1 = 271 ± 3 km/s (also now reported by Kawka et al. and Kilic et al.) and confirmed the dips as eclipses caused by an orbiting WD with a mass M2 = 0.648--0.771 Msun for M1 = 0.1--0.2 Msun. We detect both the primary and secondary eclipses during the Porb = 5.64 hr orbit and measure the secondary's brightness to be $3.5\% \pm 0.3\%$ of the primary at SDSS-g'. Assuming that the secondary follows the mass-radius relation of a cold C/O WD and including the effects of microlensing in the binary, the primary eclipse yields a primary radius of R1 = 0.043--0.039 Rsun for M1 = 0.1--0.2 Msun, consistent with the theoretically expected values for a helium core WD with a thick, stably burning hydrogen envelope. I will discuss how our future observational efforts, such as detection of the secondary semiamplitude K2, multiband high-cadence photometric eclipse observations, and cross system time-delay measurements, will determine M1, yielding accurate WD mass-radius measurement of both components, as well as a clearer indication of the binary's fate once contact is reached.

126.02

A Ground-based Measurement Of The Relativistic Beaming Effect In A Detached Double WD Binary Avi Shporer¹

¹University of California, Santa Barbara. 2:20 PM - 2:30 PM

Room 615/617

We report on the first ground-based measurement of the relativistic beaming effect (aka Doppler boosting). We observed the beaming effect in the detached, non-interacting eclipsing double white dwarf (WD) binary NLTT 11748. Our observations were motivated by the system's high mass ratio and low luminosity ratio, leading to a large beaming-induced variability amplitude at the orbital period of 5.6 hr. We observed the system during 3 nights at the 2.0m Faulkes Telescope North with the SDSS-g' filter, and fitted the data simultaneously for the beaming, ellipsoidal and reflection effects. Our fitted relative beaming amplitude is $(3.0 \pm 0.4) \times 10^{-3}$, consistent with the expected amplitude from a blackbody spectrum given the system's radial velocity amplitude. This result is a first step in testing the relation between the photometric beaming amplitude and the spectroscopic RV amplitude in NLTT 11748 and similar systems. We did not identify any variability due to the ellipsoidal or reflection effects, consistent with their expected undetectable amplitude for this system. Low-mass, helium-core WDs are expected to reside in binary systems where in some of those systems the binary companion is a faint C/O WD and the two stars are detached and non-interacting, as in the case of NLTT 11748. The beaming effect can be used to search for the faint binary companion in those systems using wide-band photometry.

126.03

A Convergence Study of Mass Transfer in a Simulated Double White Binary

Patrick M. Motl¹, J. E. Tohline², J. Frank²

¹Indiana University Kokomo, ²Louisiana State University.

2:30 PM - 2:40 PM

Room 615/617

We present evolutions of a model double white dwarf binary with a low initial mass ratio (q = 0.4). We vary both the initial depth of contact (and hence the initial mass transfer rate) as well as the numerical resolution in our Eulerian hydrodynamics code. At the highest resolution of about 47 million grid cells we find that the binary has an initially growing mass transfer rate that then declines as the binary separates through the 50 orbital periods of the simulation. The lower resolution run (evolved with about 3 million cells) of the same binary also shows evidence for stable mass transfer though the mass transfer rate is significantly higher - emphasizing the importance of numerical resolution in these simulations. In this presentation we quantify the convergence of mass transfer between donor and accretor and measure the exchange of angular momentum through orbit-averaged equations. This work has been supported in part by NASA Astrophysics Theory Program grant number NNX10AC72G. The computations were performed on Teragrid and LONI facilities.

126.04

An Extremely Deep-Eclipsing Cataclysmic Variable discovered with La Silla - QUEST

David L. Rabinowitz¹, S. Tourtellotte¹, C. Baltay¹, C. Bailyn¹, P. Coppi¹, P. Rojo², G. Folatelli², S. Hoyer² ¹Yale Univ., ²U. Chile, Chile.

2:40 PM - 2:50 PM Room 615/617

We report the discovery of an extremely deep-eclipsing cataclysmic variable with eclipse depth ~5 magnitudes, orbital period 94.657 min, and peak brightness V~18. After incidental discovery by visual inspection of wide-field CCD images acquired with the Yale University QUEST camera on the European

Observatory 1.0-m Schmidt at La Silla, we obtained photometric light curves in B, V, and R, each simultaneous with J using ANDICAM on the SMARTS 1.3m at Cerro Tololo. We also obtained light curves in U, V, i, and z with the SMARTS 1.0m and spectra covering the wavelength range 3500 to 9000 A with the Goodman spectrograph on the SOAR 4.1m. The optical light curves are periodic with a complex structure -- a short eclipse of duration 5 min and depth > 5 mags followed immediately by a long eclipse of duration 38 min and depth ~2 mags. Between eclipses the light curve varies sinusoidally with amplitude ~1 mag. We observe significant changes in the light-curve shape with wavelength, with no short-duration eclipses appearing in the J band. The spectra reveal strong Hydrogen emission lines, and a continuum that varies with light curve phase. No known radio or x-ray source coincides with the new object's location.

126.05

K-band Observations of Sub-Gap Cataclysmic Variables

Ryan T. Hamilton¹, T. E. Harrison¹, C. Tappert², S. B. Howell³ ¹New Mexico State University, ²Universidad de Valparaiso, Chile, ³NOAO. 2:50 PM - 3:00 PM Room 615/617

We present *K*-band spectroscopy of short period, ``sub-gap'' cataclysmic variable (CV) systems obtained using ISAAC on the VLT. We show the infrared spectra (IR) for nine systems below the 2-3 hour period gap: V2051 Oph, V436 Cen, EX Hya, VW Hyi, Z Cha, WX Hyi, V893 Sco, RZ Leo, and TY PsA. We are able to clearly detect the secondary star in all but WX Hyi, V893 Sco, and TY PsA. We present the first direct detection of the secondary stars of V2051 Oph, 436 Cen, and determine new spectral classifications for EX Hya, VW Hyi, Z Cha, and RZ Leo. We find that the CO band strengths of all but Z Cha appear normal for their spectral types, in contrast to their longer period cousins above the period gap. This brings the total number of CVs with moderate resolution (R \ge 2000) IR spectroscopy to forty-eight systems: six pre-CVs, thirty-one non-magnetic systems, and eleven magnetic or partially magnetic systems. We discuss the trends seen in the IR abundance patterns thus far, and highlight a potential link between anomalous abundances seen in the IR with the C IV/N V anomaly seen in the ultraviolet. We present a compilation of all systems with sufficient resolution IR observations to assess the CO band strengths, and, by proxy, obtain an estimate on the C abundance on the secondary star.

126.06

Following the Accreting Pulsating White Dwarfs in GW Lib and V455 And After their Superoutbursts Paula Szkody¹, A. S. Mukadam¹, B. T. Gaensicke², E. Bullock¹, E. J. Harpe³, A. Henden⁴, E. M. Sion⁵, D. M. Townsley⁶

¹University of Washington, ²University of Warwick, United Kingdom, ³Heritage High School, ⁴AAVSO, ⁵Villanova University, ⁶University of Alabama.

3:00 PM - 3:10 PM

Room 615/617

Accreting pulsating white dwarfs offer the opportunity to study the effects of mass transfer, rotation and accretion on the internal structure of white dwarfs, as pulsation modes in white dwarfs penetrate deep into the stars. Thirteen of these systems are now known to reside in cataclysmic variables. These objects undergo large amplitude outbursts on 20-30 yr timescales which heat the white dwarfs and move them out of their instability zones for 2-3 yrs. Following the white dwarfs as they re-enter the instability strip thus allows an unprecedented opportunity to glean information about the modes and depth of heating.

GW Lib and V455 And are two objects with accreting pulsating white dwarfs that underwent superoutbursts in 2007. We have followed these systems with ultraviolet data from GALEX and HST, and

ground-based optical data. These 2 systems show different behavior, with GW Lib remaining hot and lacking pulsations 3 yrs post outburst, while V455 And shows a return of a group of periodicities present at shorter periods than pre-outburst. These differences are being studied on the basis of the masses and rotation rates derived from the COS data.

Support for this work was provided by NASA GALEX grants NNX08AU43G, NNX09AF87G, HST grants GO-11638, GO-11639, and NSF grant AST-0607840.

127

Galaxy Clusters: Intracluster Medium and Cosmology Oral Session *Room 606*

127.01D

Sloshing Gas in Galaxy Clusters

Ryan Johnson¹, M. Markevitch², C. Jones², G. Wegner³, W. Forman²

¹Dartmouth College / Denison University, ²Harvard Smithsonian - Center for Astrophysics, ³Dartmouth College.

2:00 PM - 2:20 PM

Room 606

Despite appearing relaxed and symmetric on large scales, many galaxy clusters exhibit striking asymmetries in their core gas distributions. One mechanism for creating these asymmetries is by the bulk oscillation, or sloshing, of the core gas about the cluster gravitational potential minimum. In X-ray observations, this sloshing gas appears as sharp edges in a cluster's surface brightness distribution, with the edges demarcating the (projected) boundary between the lowest entropy gas near the sloshing core and the higher entropy outer cluster gas. Simulations have demonstrated that this sloshing may be brought about by gravitational interactions with other groups or clusters and that such interactions need not be so energetic as mergers, but that even glancing interactions may initiate this gas sloshing. Since large clusters tend to lie at the intersection of cosmic filaments, where there are potentially many such interactions, we expect that most massive clusters should be undergoing some degree of gas sloshing as a result of previous interactions with infalling groups or clusters. My dissertation explores the nature of this core gas sloshing in clusters and how we may use this phenomena as a pointer to the merger history of the system.

127.02

A Double Lobe Radio Galaxy Between Clusters: Constraints on the Intrafilament Medium Density Louise O. V. Edwards¹, D. Fadda¹, D. T. Frayer²

¹California Institute of Technology, ²National Radio Astronomy Observatory.

2:20 PM - 2:30 PM

Room 606

We have found the first bent double lobe radio source (DLRS) in a known cluster filament. This discovery has enabled us to constrain the intrafilament density (IFM) to be between $(1-10)x10^{-29}$ gm/cm³. The host filament has been observed using extensive multiwavelength photometry and confirmed with hundreds of member redshifts. It stretches from the rich galaxy cluster Abell 1763 to the nearby cluster Abell 1770, ~13Mpc away. Our recent observations from the VLA uncovered the DLRS at a distance of 3.4Mpc from the center of Abell~1763, well outside the virial radius of either cluster. We measure the jet flux and calculate the minimum pressure in the jet. Using geometric arguments to derive the orientation and bend of the jet, and assuming that the bend of the of the jet is due to ram pressure, we are able to constraint the density of the IFM. Our measurements agree with the small number of IFM estimates that currently exist, including results from different approaches such as the direct X-ray observations of Abell

222/223 and related WHIM measurements in Sculptor, as well as theoretical models. Our findings justify future searches for bent double lobe radio sources located several Mpc from cluster cores, as they may be good markers of super cluster filaments.

127.03D

On the Origins of $\mbox{H}\alpha$ Emission in the Cool Cores of Galaxy Groups and Clusters

Michael McDonald¹, S. Veilleux¹, R. Mushotzky¹

¹University of Maryland.

2:30 PM - 2:50 PM

Room 606

We present results from a survey of cooling flow clusters and groups covering nearly three orders of magnitude in mass, and 1-2 orders of magnitude in temperature and mass deposition rate, aimed at explaining the presence and morphology of warm, ionized gas in the cool cores of galaxy groups and clusters. Using the Maryland-Magellan tunable filter on the Baade 6.5-m telescope at Magellan we have taken a census of these mysterious Halpha filaments with unprecedented depth and resolution. These data have been supplemented with new and archival X-Ray (Chandra), UV (HST, GALEX, XMM-OM), near-IR (2MASS) and radio (VLA) observations. Armed with the most detailed picture of the warm, ionized gas in cooling flow clusters to date, we investigate the possible mechanisms for producing the observed morphologies (buoyant bubbles, runaway cooling, interaction with satellites, etc) as well as possible ionization mechanisms (young stars, heat conduction from the ICM, collisional heating from cosmic rays, etc). Additionally, we determine the effect of environment on the formation of ionized filaments by considering the correlation of Halpha filaments with the global mass, temperature and gas fraction of the system. Our results offer exciting new constraints, both quantitative and qualitative, for the latest models of cooling flow clusters.

127.04

Mass Function Predictions Beyond LCDM

Suman Bhattacharya¹, K. Heitmann¹, M. White², Z. Lukic¹, C. Wagner³, S. Habib¹ ¹Los Alamos National Laboratory, ²UC Berkeley, ³ICC, Barcelona, Spain. 2:50 PM - 3:00 PM

Room 606

The statistics of dark matter halos is an essential component of precision cosmology. The mass distribution of halos, as specified by the halo mass function, is a key input for several cosmological probes. The sizes of N-body simulations are now such that, for the most part, results need no longer be statistics-limited, but are still subject to various systematic uncertainties. Discrepancies in the results of recent simulation campaigns for the halo mass function remain in excess of statistical uncertainties and of roughly the same size as the error limits set by near-future observations; we investigate and discuss some of the reasons for these differences. Quantifying error sources and compensating for them as appropriate, we carry out a high-statistics study of dark matter halos from 67 N-body simulations to investigate the mass function and its evolution for a LCDM cosmology and for a set of wCDM cosmologies. We quantify the breaking of universality in the form of the mass function as a function of redshift, finding an evolution of as much as 10 % away from the universal form between redshifts z=0 and z=2. We provide a fitting formula to our results for the (evolving) LCDM mass function over a mass range of 6e11-3e15 solar-mass to an estimated accuracy of about 2 %. In the case of the wCDM cosmologies, we find that the mass function is described by the same fitting formula at an accuracy level of 5-10 % over widely varying cosmologies.

127.05 **Three-Dimensional Structure of the 1367 Abell - Coma Supercluser Jane Kaczmarek**¹, K. Hess¹, E. Wilcots¹ ¹University of Wisconsin-Madison. 3:00 PM - 3:10 PM

Room 606

We apply the IR Tully-Fisher relationship, combining measurements of the HI profiles from the ALFALFA survey and near-IR colors from 2MASS for 364 galaxies in the Abell 1367 - Coma supercluster ranging from 6000-8500 km/s. We describe the basic 3-dimensional structure of the supercluster, highlighting the known galaxy groups and compare with model of the density distribution around Coma.

128 *Evolution of Galaxies II* Oral Session *Room 607*

128.01D

The Formation and Evolution of Massive Black Holes in Cosmological Simulations

Jillian M. Bellovary¹, F. Governato², T. Quinn², M. Volonteri¹

¹University of Michigan, ²University of Washington.

2:00 PM - 2:20 PM

Room 607

Massive black holes (MBHs) are inextricably connected to the formation of massive galaxies, but their formation, evolution, and specific effects on their hosts are not clearly understood. Cosmological simulations of galaxy formation, including prescriptions for MBH formation, mergers, accretion, and feedback, are a unique way to shed light on this issue. We use a suite of simulated galaxies with a range of masses and formation histories to make predictions regarding the distribution of MBHs in galaxies as well as their fueling histories. We predict a population of ``wandering'' MBHs in the halos of massive galaxies, which are the remnant cores of tidally stripped satellite galaxies. These objects may be observed as off-nuclear ultraluminous X-ray sources if the cores retain a gas reservoir and are perturbed in some way, such as a passage near the galactic disk. Additionally, we trace the origins of gas accreted by central black holes to test the standard paradigm that quasars are fueled by major mergers. We find that in addition to major mergers, a high redshift quasar can be fueled through smoothly accreted cold flows; thus, a major merger is not a requirement for quasar activity. Bulge morphology is likely an observational relic of a galaxy's merger history and can be used to test whether a black hole's accretion has been fueled through mergers or more quiescent processes.

128.02D

Insight into the Early Evolution of Globular Clusters and Supermassive Black Holes from Panchromatic Observations of Nearby Dwarf Starburst Galaxies

Amy E. Reines¹

¹Univ. of Virginia.

2:20 PM - 2:40 PM

Room 607

In the earlier universe, both globular clusters and the seeds of supermassive black holes are believed to have formed in the progenitors of modern massive galaxies, although the details are poorly understood. Direct observations of these low-mass, distant, and hence faint systems are unobtainable with current capabilities. However, gas-rich dwarf starburst galaxies in the local universe, analogous in many ways to protogalaxies at high-redshift, can provide critical insight into the early stages of galaxy evolution

including the formation of globular clusters and massive black holes. We present a panchromatic study of nearby dwarf starburst galaxies harboring nascent globular clusters still embedded in their birth material. We also show the first example of a nearby dwarf starburst galaxy simultaneously hosting an actively accreting intermediate-mass central black hole and an extreme burst of star formation. The massive black hole in this dwarf galaxy is unusual in that it is not associated with a bulge, a nuclear star cluster, or any other well-defined nucleus, likely reflecting an early phase of black hole and galaxy evolution that has not been previously observed.

128.03D

Application of a New AGN Diagnostic to Infrared Galaxies: Unveiling Obscured AGNs

Stephanie Juneau¹, M. Dickinson² ¹University of Arizona, ²NOAO. 2:40 PM - 3:00 PM

Room 607

I will present a new excitation diagnotic that allows us to identify the presence of active galactic nuclei (AGNs) in galaxies out to redshift ~1. Our understanding of galaxy evolution relies on disentangling the roles of star formation and AGN, two phenomena affecting the fate of galaxies. Although it has become increasingly clear that supermassive black holes (SMBHs) are ubiquitous, the details of their connection to their host galaxies remain open questions. For instance, what fraction of SMBHs are actively accreting? How does that fraction relate to the rate of star formation? To address these topics, I will describe a census of AGNs within 70-micron selected galaxies from the Far-Infrared Deep Extragalactic Legacy survey (FIDEL). This population of galaxies includes the main contributors to the star formation rate density at redshift ~ 1. We find that although only ~10-12% of 70-micron galaxies with emission lines host a strong, X-ray detected AGN, the AGN fraction reaches ~40% when including systems with low-level activity. Furthermore, the diagram reveals AGNs that are misidentified in the most sensitive Chandra X-ray observations (reaching 2 Msec in the GOODS-North field). I will show evidence that a large number of these "missed" AGNs are likely Compton-thick.

128.04

High-z Superwinds from Massive Star-forming Clumps

Sarah Newman¹, R. Genzel², SINS team

¹*UC Berkeley,* ²*MPE, Germany.* 3:00 PM - 3:10 PM

Room 607

We have observed large-scale galactic outflows from resolved clumps in several z^2 galaxies in emission. The observations were made using SINFONI/VLT integral field spectroscopy with adaptive optics of H α , [NII] and [SII]. We estimate the outflow rate from these H α -bright, rapidly star-forming clumps as several times the SFR. We also estimate the lifetime of these clumps based on the stellar ages, the gas exhaustion timescale, the metal enrichment timescale and the expansion timescale. We can understand these massive outflow rates in the context of superwinds generated by feedback from active star formation. This result is highly significant as this is the first time that outflows have been detected from spatially resolved clumps, and the information gathered on the fate of these clumps will help us to better understand galaxy formation and evolution at the redshifts at which today's massive galaxies were formed. This work was possible thanks to the National Science Foundation's Graduate Research Fellowship Program.

128.05

First Results from HIPPIES: Constraint on the Very Bright End of Galaxy Luminosity Function at z >~ 7 Haojing Yan¹, HIPPIES Project

¹CCAPP, Ohio State University. 3:10 PM - 3:20 PM

3.10 F M = 3.20

Room 607

We present the first results from the Hubble Infrared Pure Parallel Imaging Extragalactic Survey (HIPPIES), which utilizes HST pure parallel orbits to do deep imaging along a large number of random sightlines. One of the key goals of HIPPIES is to search for candidate galaxies at z>7 and to address the very bright-end of the luminosity function at these redshifts. We report the Ys-dropouts discovered among the 30 WFC3 fields observed in Cycle 17(program 11700, PI. M. Trenti; and program 11702, PI. H. Yan), and compare to the initial Y-dropout selection results from 8 WFC3 fields recently observed in Cycle 18 (program 12286, PI. H. Yan). We acknowledge the support of NASA grant HST-GO-11702.*.

128.06

Near-infrared Imaging And Z=7 Galaxy Candidates In The GOODS-North Field

Nimish P. Hathi¹, B. Mobasher², P. Capak³

¹Carnegie Observatories, ²UCR, ³Caltech.

3:20 PM - 3:30 PM

Room 607

Near-infrared (NIR) imaging covering the full GOODS-North (GOODS-N) field has been done only from the ground, using the CFHT and the Subaru telescopes. The lack of space-based NIR imaging in this field has increased the importance of these ground-based observations. We present the co-added/combined NIR images in the GOODS-N field obtained using the CFHT/WIRCam and the Subaru/MOIRCS instruments. MOIRCS observations cover approx. 60% of the central GOODS-N field, while WIRCam observations cover a much wider area. These archival imaging data in J and Ks filters were reduced independently and then combined to increase the depth of these observations in the ACS covered GOODS-N region. These combined images cover the GOODS-N area to a depth of about 25 AB mag in both filters. We also examine the feasibility of using (z-J) vs. (J-Ks) color selection in the ACS covered GOODS-N region to identify bright z-band dropouts, which are galaxy candidates at z=7. Our preliminary results indicate a very low surface density (approx. 0.01 objects per sq. arcmin) of bright (< 26 mag) z=7 galaxy candidates in the GOODS-N field. We discuss the importance of these NIR data, and the results obtained from our z-band dropout search.

129

HAD V History of Astronomy Oral Session Room 613/614

129.01

The Legendary Fourth-Century Total Solar Eclipse in Georgia: Fact or Fantasy? Jefferson Sauter¹, I. Simonia¹, F. Stephenson¹, W. Orchiston¹ ¹James Cook University, Australia. 2:00 PM - 2:15 PM *Room 613/614* Medieval Georgian accounts of a sudden darkening of the sky are studied in detail. Though aspects of the story were likely embellished or fantastical, specific clues in the written sources suggest a total solar eclipse (TSE) from the 4th century AD. We examine the local circumstances of a likely candidate, the TSE of 6 May 319, using computer simulations and accounting for visibility corrections and constraints on
the accumulated clock error (Δ T). If the accounts do describe this TSE, the value of Δ T inferred from the written sources would agree well with the range of values derived from Stephenson (1997). Additional analysis shows why this eclipse may have seemed uniquely remarkable to observers at the presumed location.

129.02

Declinations in the *Almagest*: An Evaluation and Comments on their Use by Tycho Brahe and Edmond Halley

John C. Brandt¹, P. Zimmer¹, P. B. Jones²

¹Univ. of New Mexico, ²Univ. of Arizona.

2:15 PM - 2:30 PM

Room 613/614

The Almagest (Book VII, Chapter 3: Toomer 1998) gives 54 stellar declinations attributed to Timocharis, Aristyllus, Hipparchus, and Ptolemy ("As found by us"). We evaluate these declinations (δ) by comparing them to precessed modern positions (d) obtained by using U.S. Naval Observatory software. A recent HIPPARCOS catalogue is the source of positions, proper motions, and parallaxes, and radial velocities come from the Yale Bright Star Catalog. The standard deviation (σ) is computed for $\Delta = \delta - d$ for a plausible range of years for each observer. The minimum standard deviation, σ_{min} , determines the accuracies and epochs of observation assuming that an observer's observations were taken at approximately the same time. The results are: Timocharis, $\sigma_{min} = 0.135^{\circ}$ and $\langle \Delta \rangle = +0.022^{\circ}$ at 295 BC: Aristyllus, $\sigma_{min} = 0.089^{\circ}$ and $\langle \Delta \rangle = -0.004^{\circ}$ at 258 BC; Hipparchus, $\sigma_{min} = 0.113^{\circ}$ and $\langle \Delta \rangle = +0.010^{\circ}$ at 128 BC; and Ptolemy, σ_{min} = 0.199° and < Δ > = +0.005° at 115 AD. The precisions (σ_{min}) are remarkable, the mean errors ($\langle \sigma \rangle$) are small, and the dates are compatible with the historical evidence except for Ptolemy. The Δs for individual observers are approximately Gaussian except Timocharis's value for Arcturus at $5.6\sigma_{min}$ which appears to be erroneous; our results are based on 53 declinations. The study of Almagest declinations by Maeyama (1984) uses the same approach and input data from the catalogue by Boss (1910). The results of the two studies are close, but with differences. Our values should be an improvement because of improved input data. We comment on the use of *Almagest* declinations by Tycho Brahe and Edmond Halley.

129.03

Kepler's Cosmos And The Lathe Of Heaven

Kenneth Brecher¹ ¹Boston University. 2:30 PM - 2:45 PM

Room 613/614

Johannes Kepler's *Mysterium Cosmographicum*, published in 1596, presented his vision of the geometrical structure of the solar system. Kepler sought to account for the number of planets, thought to be six, as well as their orbital radii. He assigned orbits to the planets in three-dimensional space. Kepler proposed that the planets move on six spheres inscribed within and circumscribed around the five platonic solids. How did he arrive at his model? By his own account reported in the book, the central idea occurred to him while giving a lecture about planetary conjunctions. But was this revelation the origin of the model? In this presentation, we discuss the artistic, scientific and mathematical environment in which Kepler was immersed in late 16th century Europe. Examples will be shown of some of the readily available inscribed polyhedra that he may have seen - printed in widely circulated books, included in well-known paintings and engravings, and displayed as three dimensional ornamentally turned sculptures. It is highly likely that he saw such physical models five years later while in the employ of Rudolf II who was an avid ornamental turner. Layered polyhedral ivory turnings were

made by the nobility with what were then fairly common lathes. Kepler himself wanted to have his own celestial model made into a punch bowl! Therefore, it seems plausible that Kepler had seen models of inscribed platonic solids well before 1596. Later in life Kepler reprinted the *Mysterium Cosmographicum* with very little fundamental change in its outlook, even after having found what we now call Kepler's three laws of planetary motion. His interest in nested polyhedra may well have preceded any astronomical evidence or geometrical reasoning, arising from artistic and aesthetic encounters that occurred early in his life. Project LITE is supported by the NSF through DUE Grant # 0715975.

129.04

Astronomy with a Difference: China Nathan Sivin¹

¹University of Pennsylvania. 2:45 PM - 3:30 PM Room 613/614

Chinese astronomy, observational and computational, is the only one of the world's traditions minutely documented and uninterrupted in its evolution for the last two thousand years. Its independence from Western influence for most of that period, and the fundamental differences in the ways it was thought through and organized, make it valuable for studying astronomical possibilities never explored elsewhere. This short talk will sketch its special character and the nature of the historical research going on in China and elsewhere.

130

Planetary Nebulae and Supernova Remnants Oral Session *Room 609*

130.01

Infrared Spectroscopy of Late Stage Post-AGB Stars

Alexa H. Hart¹, J. Hora², L. Cerrigone³, G. Umana⁴, C. Trigilio⁴, M. Cohen⁵, M. Marengo⁶ ¹University of Denver & Harvard-Smithsonian Center for Astrophysics, ²Harvard-Smithsonian Center for Astrophysics, ³Max-Planck-Institut fuer Radioastronomie, Germany, ⁴INAF-Osservatorio Astrofisico de Catania, Italy, ⁵University of California at Berkeley, ⁶Iowa State University. 2:00 PM - 2:10 PM

Room 609

During their pilgrimage towards Planetary Nebulae (PNe), dust-enshrouded post-AGB stars undergo a structural and perhaps chemical transformation. Many potentially responsible shaping mechanisms have been proposed, including an axisymmetric super wind, several types of binary interactions and magnetic confinement. During this critical phase, the central star is typically obscured at optical wavelengths; infrared emission from the circumstellar envelope provides a window into the processes occurring in the interior region. I present spectra (from Spitzer's IRS and MMIRS on the Magellan Clay Telescope) of a sample of late post-AGB stars designed to bracket the transition from post-AGB to PN. These data reveal important clues about conditions in the circumstellar environment during this enigmatic phase.

130.02D

Cosmic Ray Acceleration at Supernova Remnant Shocks Daniel Castro $^{\rm 1}$

¹*Harvard Smithsonian Center for Astrophysics.* 2:10 PM - 2:30 PM

Room 609

Observational evidence increasingly supports the scenario where cosmic rays are accelerated at supernova remnant (SNR) shocks. Both thermal and non-thermal emission from these objects, in a wide range of wavelengths, indicate the presence of extremely energetic particles in SNRs, and the development of analytical and semi-analytical models of SNR evolution where diffusive shock acceleration (DSA) is efficient allow for constraining the nature of cosmic ray production. The research presented in this talk focuses on the impact of DSA on the evolution and observational properties of SNRs, and it is divided in three main parts. Firstly, an X-ray study of the morphology and spectral properties of SNR G296.1-0.5 is performed, using the XMM-Newtonn X-ray Observatory. Modeling of the observational characteristics of this SNR suggest the remnant is in the adiabatic expansion phase, and is possibly the result of the core collapse of a massive progenitor. The detection of a bursting compact source in the direction of the remnant, and its nature and possible association with the SNR, is also discussed. Secondly, a semi-analytical model is presented, which considers the modifications to the evolution and emission characteristics of SNRs in the Sedov-Taylor phase, imposed by DSA. This study shows how efficient cosmic ray acceleration impacts the analysis of SNRs in this evolution phase, and how the results diverge from the standard model when the acceleration process is efficient. Finally, the gamma-ray observations, with the Fermi LAT, of MeV-GeV emission coincident with four SNRs are analyzed. These SNRs show evidence of interaction with dense molecular clouds, from OH maser studies, and the gamma-ray emission in their directions is explained in this study as the result of pion-decay emission from the dense molecular material interacting with cosmic rays accelerated at the shocks of these remnants.

130.03D

Cosmic-ray Acceleration Efficiency of the Supernova Remnants RCW 86 and SNR 0509-67.5 Eveline A. Helder¹, J. Vink¹

¹Utrecht University, Netherlands.

2:30 PM - 2:50 PM

Room 609

Since their discovery in 1912, it has been a problem to identify the main sources of Galactic cosmic rays. This is an important issue, as accelerating these particles requires an enormous amount of energy: they contribute one third to the energy density of the inter stellar medium. For decades, the main candidates for accelerating Galactic cosmic rays have been the shocks of supernova remnants. There is plenty evidence for highly energetic cosmic-ray electrons at the shock fronts of supernova remnants. However, 99% of the cosmic-ray energy is contained in cosmic-ray protons.

We measured the total cosmic-ray acceleration efficiency by combining shock velocities with proton temperatures behind the shock fronts of the young supernova remnants RCW 86 and SNR 0509-67.5. We show that the temperatures are lower than expected from the shock velocities. From this study, we conclude that over 10% of the pressure behind the shock is contributed by cosmic rays.

130.04D

Multi-wavelength Modeling Of SNRs: Implications On Cosmic Ray Acceleration Miguel \mbox{Araya}^1

¹Purdue University. 2:50 PM - 3:10 PM Room 609

A spectral study of non-thermal filaments is carried out with data from a deep Chandra observation of Cassiopeia A, a young supernova remnant (SNR). The diffusion model applied explains the properties observed, such as the spectral hardening going outward, and allows for an estimation of the magnetic

field, level of turbulence and shock obliquity. Using these results, and combining archival data taken at radio and infrared wavelengths with state-of-the-art measurements at X-ray and gamma-ray energies, a spectral energy distribution (SED) is assembled and modeled. The non-thermal SED is explained partly with a two-zone leptonic model. Synchrotron emission from the electrons can account for data from radio to X-ray wavelengths. Much of the GeV-TeV emission can also be explained by a combination of bremsstrahlung emission and inverse Compton scattering of infrared photons. However, the model cannot fit a

distinct feature at GeV energies. This feature can be well accounted for by a pion-zero emission component to the model, providing evidence for cosmic ray production in Cas A. A similar SED is assembled for Tycho's SNR. The results do not allow to conclude anything firmly, although the leptonic scenario for this case might be able to explain the data.

130.05

The Origin and Evolution of the Nonthermal Emission in Cassiopeia A

Daniel Patnaude¹, R. Fesen², J. Laming³, J. Vink⁴

¹Smithsonian Astrophysical Observatory, ²Dartmouth College, ³NRL, ⁴University of Utrecht, Netherlands. 3:10 PM - 3:20 PM

Room 609

Cassiopeia A is one of only a handful of Galactic supernova remnants to show variations in nonthermal emission on measureable timescales. With 10 years worth of Chandra observations of Cas A, I will show how the nonthermal emission has decreased by ~ 1.5%/yr, or about twice as fast as the decline seen in the radio emission. On smaller scales, I will demonstrate that the nonthermal emission knots and filament are not uniformly distributed across the face of the remnant, with the smallest scale features localized along and interior of the so-called bright ring. This would seem to suggest that the observed short term variations are not occurring at the forward shock, but somewhere in the interior, possibly at the contact discontinuity.

131

YSO's Etc. II Oral Session *Room 604*

131.01

Fitting Spectral Energy Distributions of Protostars in the Taurus Star-Forming Region Jillian Tromp¹, S. Terebey¹, D. Padgett², L. Rebull², A. Noriega-Crespo², Taurus Spitzer Legacy Team ¹*California State University, Los Angeles, ²Caltech, Spitzer Science Center.* 2:00 PM - 2:10 PM

Room 604

We present data for the brightest far-infrared objects in the Taurus star-forming region comprising a sample of eighty sources. We fit observed spectral energy distributions (SEDs) of the embedded population from the Taurus Spitzer Legacy Survey using a grid of pre-computed model SEDs. Our 70 micron flux-limited sample is above 0.6 Jy, and is comprised of 67 young stellar objects (26 Class I, 12 Flat Spectrum, 26 Class II, 3 Class III), 10 galaxies, and 3 miscellaneous objects (a planetary nebula, carbon star, and background giant). The criterion for this sample is biased toward the selection of protostars since excess emission in the far-infrared is indicative of the dust enshrouding embedded sources. Fainter 70 micron objects in the Taurus Spitzer Legacy data set are predominately background galaxies. The observed SEDs are fit using the YSO model SED grid from Robitaille et al., 2007, computed using a Monte-Carlo radiation transfer code from Whitney et al., 2003. Updated constraints on the parameters involved in low-mass star formation theory are presented.

131.02D

The Characterization of Volatiles Associated with Young Stellar Objects

Kari A. Wojtkowski¹, E. L. Gibb¹, B. A. Wilking¹, S. S. Shenoy² ¹Univ. Of Missouri St. Louis, ²NASA Ames Research Center.

2:10 PM - 2:30 PM

Room 604

We present column densities for CO_2 and H_2O ice toward ~30 Young Stellar Objects (YSOs) in the Rho Ophiuchi dark cloud. We compare abundance ratios with the spatial distribution of the YSOs, their evolutionary state, and their local environment. In addition, we consider similarities and differences between the abundance ratios in Rho Ophiuchi, Taurus, and background objects in order to investigate possible differences due to regions of low mass star formation, low and high mass star formation, and the quiescent interstellar medium. While Taurus and background objects toward three dark clouds have been extensively studied (see, for example, Zasowski et al., 2009 and Whittet et al. 2009), no large study toward Rho Ophiuchi has been completed to date. However, variations in abundance ratios due to the spatial distribution of YSOs in the molecular cloud have been found. For example, Pontoppidan (2006) found an enhancement of CO_2 and CO ice toward the Ophiuchus-F core, but with a sample size of five sources. Our study provides more information regarding differences in abundance ratios related to the spatial distribution of the sources by considering YSOs throughout the entire dark cloud rather than a single core. In addition, our large sample size allows a better statistical comparison with YSOs in other environments, as well as the evolutionary state of YSOs within Rho Ophiuchi.

131.03

Mid-Infrared Variability in Protoplanetary Disks with Gaps and Holes Catherine $\mbox{Espaillat}^1$

¹Harvard-Smithsonian Center for Astrophysics.

2:30 PM - 2:40 PM

Room 604

Forming planets should interact with the surrounding accretion disk, clearing the material around themselves and leaving behind gaps in the disk. Stars with inner holes in their disks have been detected and are labeled as transitional objects. A few years ago, Spitzer identified a new class of "pre-transitional disks" which have gaps rather than holes - they have an inner disk, a gap, and an outer disk. In several cases, millimeter imaging has confirmed the presence of these cavities. Recently, we obtained multi-epoch Spitzer IRS spectra for a number of transitional and pre-transitional disks and find that infrared variability is a common phenomenon in such objects. Using sophisticated irradiated accretion disk models we explore the possible causes for such variability by comparing spectral energy distributions to the observations. The variability observed in transitional and pre-transitional disks has important implications on the structure of protoplanetary disks.

131.04D

Morphological Complexity of Protostellar Envelopes: Structure and Kinematics John J. Tobin $^{\rm 1}$

¹Univ. Of Michigan Ann Arbor. 2:40 PM - 3:00 PM Room 604

The morphology and kinematics of infalling envelopes around protostars determine the structure of the forming protostellar disk and reflect back on the initial properties of their parent dark clouds. Axisymmetric envelopes are often used in comparison to observations due to simplicity; however, 8 micron shadow images from Spitzer show that the dense envelopes around Class 0 protostars are generally morphologically complex, often filamentary, and frequently non-axisymmetric. The observed envelope structure indicates a likely origin in turbulent cloud structure rather than a quasi-static formation and increase the likelihood of fragmentation during collapse, forming close binaries. This complex complex envelope structure is observed in regions spatially distinct from outflow cavities, and often show no systematic alignment perpendicular to the cavities. To further characterize these systems, I have observed them in the dense gas tracers N2H+, N2D+, and ammonia which closely follow the extinction morphology. The magnitude of the velocity gradients on R ~ 10000 AU scales indicates that the velocity structure, which has historically interpreted as rotation, may really be large-scale infall. Furthermore, several systems show large velocity gradients and/or linewidths near the protostar, as expected for infall or increased rotational velocity in the inner envelope. Comparisons with threedimensional filamentary and symmetric rotating collapse models indicate that the position-velocity structure seen in many systems is better reproduced by filaments than sheets or spheres. These results strongly show that the structure of the envelope must be considered when interpreting the velocity field.

131.05

Imaged Gaps in Protoplanetary Disks as Probes of Growing Planets Hannah Jang-Condell $^{\!\!1}$

¹Univ. of Maryland/NASA-GSFC.

3:00 PM - 3:10 PM

Room 604

As planets grow in size, they begin to dynamically clear out gaps in disks. Planets above about 30 Earth masses (0.1 Jupiter masses) can clear about half the material along their orbital paths, but until they grow in size to at least a Jupiter mass (300 Earth masses), these gaps do not significantly affect the spectral energy distribution. However, these gaps are potentially observable in spatially resolved imaging both in scattered light and in thermal continuum emission. Optical to near-infrared images trace out scattered light from the structure of the surface of the gap. Infrared to radio wavelengths trace radiative cooling and heating due shadowing of stellar illumination on the gap. I present observations of gaps in spatially resolved images of protoplanetary disks and compare them to analytical models to constrain the masses of planets that might be creating the gaps. If these gaps are indeed indicative of planet formation, the ages of the disks and locations of the gaps give a direct probe of the planet formation process. As we better understand where and when planets form, the better we can understand the distribution of exoplanet masses and orbital properties. This work was supported by the Michelson Fellowship Program, under contract with JPL and funded by NASA; JPL is managed for NASA by the California Institute of Technology.

131.06D

A Search for Low Mass Stars and Substellar Companions and A Study of Circumbinary Gas and Dust Disks

David R. Rodriguez¹

¹University of California, Los Angeles.

3:10 PM - 3:30 PM

Room 604

We have searched for nearby low-mass stars and brown dwarfs and have studied the planet-forming environment of binary stars.

We have carried out a search for young, low-mass stars in nearby stellar associations using X-ray and UV source catalogs. We discovered a new technique to identify ~10-100 Myr-old low-mass stars within ~100 pc of the Earth using GALEX-optical/near-IR data. We present candidate young stars found by applying

this new method in the ~10 Myr old TW Hydrae and Scorpius-Centaurus associations. In addition, we have searched for the coolest brown dwarf class: Y-dwarfs, expected to appear at temperatures <500 K. Using wide-field near infrared imaging with ground (CTIO, Palomar, KPNO) and space (Spitzer, AKARI) observatories, we have looked for companions to nearby, old (2 Gyr or older), high proper motion white dwarfs. We present results for Southern Hemisphere white dwarfs. Additionally, we have characterized how likely planet formation occurs in binary star systems. While ~20% of planets have been discovered around one member of a binary system, these binaries have semi-major axes larger than 20 AU. We have performed an AO and spectroscopic search for binary stars among a sample of known debris disk stars, which allows us to indirectly study planet formation and evolution in binary systems. As a case study, we examined the gas and dust present in the circumbinary disk around V4046 Sagittarii, a 2.4-day spectroscopic binary. Our results demonstrate it is unlikely that planets can form in binaries with stellar semi-major axes of ~10s of AU. This research has been funded by a NASA ADA grant to UCLA and RIT.

132

Interstellar Medium: HII Regions Oral Session Room 608

132.01

The GBT Galactic HII Region Discovery Survey Source Catalog

Thomas M. Bania¹, L. D. Anderson², D. S. Balser³, R. T. Rood⁴

¹Boston University, ²Laboratoire d'Astrophysique de Marseille, France, ³NRAO, ⁴University of Virginia. 2:00 PM - 2:10 PM

Room 608

The Green Bank Telescope (GBT) HII Region Discovery Survey (HRDS) has doubled the number of known HII regions in the Galactic zone 343 deg < Lgal < 67 deg with |Bgal| < 1 deg. We detected 603 discrete Hydrogen radio recombination line (RRL) components at 9 GHz (3cm) from 448 targets. Our targets were selected based on spatially coincident mid-infrared and 20 cm radio continuum emission. Such sources are almost invariably HII regions; we detect hydrogen RRL emission from 95% of our target sample. The sensitivity of the GBT and the power of its spectrometer together made this survey possible. Here we report on the HRDS catalog of the measured properties of the RRL and continuum emission from the survey nebulae. The derived survey completeness limit, 180 mJy at 9 GHz, is sufficient to detect all HII regions ionized by single O-stars to a distance of 15 kpc. These recently discovered nebulae share the same distribution on the sky as does the previously known census of Galactic HII regions. On average, however, the new nebulae have fainter continuum fluxes, smaller continuum angular sizes, fainter RRL intensities and smaller RRL line widths. Though small in angular size, many of our new nebulae show little spatial correlation with tracers associated with extremely young HII regions, implying that our sample spans a range of evolutionary states. We discovered 34 first quadrant negative-velocity HII regions, which lie at extreme distances from the Sun and appear to be part of the Outer Arm. We found RRL emission from 211 Spitzer GLIMPSE 8 micron ``bubble'' sources, 65 of which have been catalogued previously. It thus appears that nearly all GLIMPSE bubbles are HII regions and that ~50% of all Galactic HII regions have a bubble morphology at 8 microns.

132.02

Galactic Structure As Probed By The GBT HRDS

Loren D. Anderson¹, T. M. Bania², D. S. Balser³, R. T. Rood⁴ ¹Laboratoire d'Astrophysique de Marseille, France, ²Boston University, ³NRAO, ⁴University of Virginia. 2:10 PM - 2:20 PM

Room 608

Studies of external galaxies show that HII regions are excellent tracers of galactic structure. They are zero-age objects compared to the age of their host galaxy; they map the current locations of massive star formation, which trace spiral arms. Until recently the number of Milky Way HII regions with known distances was relatively small. The new GBT HII Region Discovery Survey (HRDS) has doubled the number of known first Galactic quadrant HII regions, giving us a much larger sample for Galactic structure studies. Here we report on kinematic distance determinations for HRDS sources located in the Galactic longitude range of 18° to 65°. These first quadrant sources suffer from the well known kinematic distance ambiguity (KDA): each measured recombination line velocity maps to two possible kinematic distances, a "near" and a "far" distance. We resolved the KDA for nearly 200 HRDS sources by making HI emission/absorption experiments using data from the VLA Galactic Plane Survey. The HRDS targets are nearly all at the far kinematic distance, which indicates that their small angular size is due to a large distance from the Sun rather than a small physical size. When combined with kinematic distances for the sample of previously known HII regions, the face-on map of first quadrant star forming regions shows strong evidence for Galactic structure. The map shows two spiral arc features that have mean Galactocentric radii of ~4.5 and ~6.0 kpc. Structures at these locations are generally associated with the Scutum and Sagittarius arms, respectively. The HRDS has also detected a significant number of very distant sources beyond the Solar orbit that show excellent agreement with what has been called the Outer Arm, and agree well with the warp and flaring seen in the CO and HI layers.

132.03

Metallicity Distribution in the Milky Way Disk

Dana S. Balser¹, R. T. Rood², T. M. Bania³, L. D. Anderson⁴ ¹NRAO, ²University of Virginia, ³Boston University, ⁴Lab. d Astrophys. de Marseille, France. 2:20 PM - 2:30 PM

Room 608

Galactic chemical evolution models are important for understanding how galaxies form and evolve. A key observational constraint for these models is the spatial distribution of abundances in the Galaxy. We use hydrogen radio recombination line and continuum free-free emission observed with the Green Bank Telescope to calculate electron temperatures in 81 Galactic HII regions. Since metals, such as oxygen, are the main coolants in the photo-ionized nebular gas, the electron temperature is directly related to the distribution of heavy elements in the Milky Way. We convert the electron temperatures to metallicity (12 + Log(O/H), based on a sub-sample of objects with both electron temperature and O/H determinations. We find a radial metallicity gradient in the Galactic disk of about -0.03 to -0.06 dex/kpc with no significant discontinuity from 4-18 kpc. This is in contrast to previous studies that found a discontinuity in the gradient at 10 kpc. The radial metallicity gradient varies with azimuth, however, suggesting that the Galactic disk is not uniformly mixed as is often assumed in chemical evolution models.

The new GBT HRDS Galactic HII regions will sample a new zone in Galactic azimuth since they are systematically at the far kinematic distance. Electron temperature determinations for the HRDS nebulae may provide direct evidence for local enrichment. Moreover, the negative velocity HRDS sources are not only at the important Galactocentric radius zone of ~9-12 kpc, but also lie at very large distances, > 12 kpc, from the Sun. Electron temperature determinations for these nebulae will probe the metallicity of an entirely new part of the Milky Way.

132.04D

What Drives the Expansion of Giant HII Regions?: A Study of Stellar Feedback in 30 Doradus Laura A. Lopez¹, M. Krumholz¹, A. Bolatto², J. X. Prochaska¹, E. Ramirez-Ruiz¹ ¹UC Santa Cruz, ²University of Maryland College Park.

2:30 PM - 2:50 PM

Room 608

Observations demonstrate that star formation is an inefficient and slow process. This result can be attributed to the injection of energy and momentum that prevents free-fall collapse of molecular clouds. The mechanism of this feedback is debated theoretically: possible sources of pressure include the classical warm HII gas, the hot gas generated by shock-heating from stellar winds and supernovae, direct radiation from stars, and the dust-processed radiation field trapped inside the HII shell. In this talk, I present observational measurements of the pressures associated with each component listed above in the giant HII region 30 Doradus in the Large Magellanic Cloud. For this analyses, we have used high resolution, multi-wavelength images (radio, infrared, optical, and X-ray) to map these pressures as a function of position. We find that radiation pressure dominates within 50 pc of the central star cluster, R136, while the HII gas pressure dominates at larger radii. By contrast, the dust-processed radiation pressure and hot gas pressure are generally weak and not dynamically important, although the hot gas pressure may have played a more significant role at early times. I discuss the implications of these results regarding confinement/leakage of the hot gas from the HII shell and the early dynamics of 30 Dor.

132.06

Spatially Resolved 3-micron Spectroscopy of HII Regions Erin C. Smith¹, I. S. McLean²

¹NASA Ames Research Center, ²UCLA.

3:00 PM - 3:10 PM

Room 608

We used narrow band 3 micron emission maps of the Orion Bar, M17 and S-106 to investigate the distribution of 3.3 micron polycyclic aromatic hydrocarbon (PAH) emission with respect to K-band emission. In each HII region the prominent 3.3 micron emission was offset from or displayed a different morphology than the K band emission. In the Orion Bar PAH emission was offset by 2-3 arcseconds, in M17 the 3 micron emission exhibited distinctly shell-like morphology, and in S-106 PAH emission was bar-like in distribution. We also obtained 3-5 micron spectra of the regions with prominent 3 micron emission within each HII region using NIRSPEC at Keck Observatory. By systematically stepping the NIRSPEC slit across the regions' extent we obtained data cubes with 2 spatial and 1 spectral dimension. Spectra at each spatial position were fitted with a series of Gaussians to measure the central wavelength, FWHM and total flux of each feature. Spatial distribution and spectral variation of the 3.3 micron hydrocarbon emission feature and its associated features at 3.4, 3.46, 3.51 and 3.56 microns were examined and compared to Hell, Pfund-gamma and Pfund-delta (Hydrogen) atomic emission. Hydrocarbon emission exhibited the same morphological variations as seen in the narrow band images. While the distribution of individual hydrocarbon features was similar, there were correlations observed between the 3.4 and 3.51 micron emission features as well as spectral variations in the 3.4 micron feature shape between the ionized and molecular regions in the Orion Bar.

Ionization Parameter: A Diagnostic of Radiation Pressure Dominated HII Regions

Sherry Yeh¹, C. D. Matzner¹

¹University of Toronto, Canada.

3:10 PM - 3:20 PM

Room 608

When irradiation is sufficiently intense, the structure of an HII region will be dominated by radiation pressure and stellar winds, rather than ionized gas pressure. This state is of considerable interest because of its role in the formation of massive stars, the disruption of giant molecular clouds, and the evolution of starburst galaxies. We discuss the usefulness of the ionization parameter U, as often derived from observed line ratios between species which exist only in ionized gas, as a diagnostic for the radiation pressure-dominated state. In ionization-bounded directions, U cannot exceed a maximum value U_{max} determined by equilibrium between radiation and gas pressure forces. Lower values of U will occur, however, when the pressure of shocked stellar winds is significant, or when neutral gas is broken into clumps with sufficiently small radii of curvature. Applying these considerations to a prominent ionized shell around 30 Doradus and to the inner starburst region of M82, along with Cloudy simulations, we conclude that both are dominated by a combination of radiation pressure and shocked winds.

132.08

The Fifth ISM Phase as Revealed by Faraday Rotation Carl E. Heiles¹

¹UC, Berkeley.

3:20 PM - 3:30 PM

Room 608

In the diffuse ISM, phases are classically categorized as largely ionized or neutral. The neutral phases come in two flavors, the Cold and Warm Neutral Media (the CNM and WNM), which have typical temperatures ~50 and ~5000 K. The ionized phases also come in two flavors, again classified by temperature: the Warm and Hot Ionized Media (the WIM and the HIM), which have typical temperatures ~8000 and ~10⁶ K. There lurks a fifth phase, the Warm Partially Ionized Medium (WPIM). This is not widely recognized, mainly because it's presence is hard to establish observationally. It is well represented by the Local Interstellar Cloud (LIC), whose properties are very well specified in a series of papers by Redfield and Linsky. This fifth phase has a relatively high electron column but low emission measure, so it is not easily seen in H alpha. However, if the region is permeated by a typical magnetic field (~6 microGauss), then it can produce a recognizable signature in Faraday rotation. We show a few examples and discuss the potential for large-scale mapping of this fifth ISM phase. Support for this work was provided in part by NSF grant AST-0908572.

133

Star formation in Extragalactic Systems Oral Session *Room 4C-4*

133.02D **The First Stars: Multiplicity, Rotation Speeds, and Feedback Athena Stacy¹** ¹University of Texas at Austin. 2:10 PM - 2:30 PM

Room 4C-4

We investigate the formation of metal-free, Population III, stars within a minihalo at z^{20} with a smoothed particle hydrodynamics simulation,

starting from cosmological initial conditions. Employing a hierarchical, zoom-in procedure, we achieve sufficient numerical resolution to follow the collapsing gas in the center of the minihalo up to number densities of 10^{12} cm⁻³. We then study the protostellar accretion onto the initial hydrostatic core, which we represent as a growing sink particle. We continue our simulation for 5000 years after the first sink particle has formed. During this time period, a disk-like configuration is assembled around the first protostar. At the end of the simulation, a small multiple system has formed, dominated by a binary with masses 40 M_{sol} and 10 M_{sol}. If Pop III stars were to form typically in binaries or small multiples, the standard model of primordial star formation, where single, isolated stars are predicted to form in minihalos, would have to be modified. As these sinks grow we furthermore measure the velocities and angular momenta of all particles that fall onto these protostellar regions. This allows us to determine the angular momentum of the sinks and estimate the rotational velocity of the Pop III stars expected to form within them. We find that there is sufficient angular momentum to yield rapidly rotating stars, with velocites close to break-up speed, providing a large enough spin to potentially lead to a GRB.

133.03D

Testing the Star Formation Law in Bulgeless Disk Galaxies

Linda C. Watson¹

¹Ohio State University. 2:30 PM - 2:50 PM

Room 4C-4

Recent work has provided constraints on the physics that sets the star formation efficiency in varying environments of the interstellar medium. However, a single theory for star formation has yet to stand out among its peers. I will present results from our study of the relation between the surface density of gas and star formation rate in twenty bulgeless disk galaxies using data from the VLA, IRAM 30m, MDM, and Spitzer IRAC. The general motivation for our study is to test the predictive power of current theories with substantially improved observations of late-type and low-mass disks. We specifically study star formation and the properties of the cold and warm interstellar medium above and below a circular velocity of 120 km/s (stellar mass $\sim 10^{10}$ solar masses), where Dalcanton et al. (2004) found that edge-on galaxies show an abrupt transition in their dust scale heights. I will discuss the location of our low- and high-mass galaxies on the star formation law, with a focus on the scale of physical processes that affect star formation.

133.04D

The HERACLES View of Molecular Gas in the Outer Disks of Galaxies

Andreas Schruba¹, A. K. Leroy², F. Walter¹, HERACLES team

¹Max Planck Institute for Astronomy, Germany, ²National Radio Astronomy Observatory.

2:50 PM - 3:10 PM

Room 4C-4

For 24 nearby spiral galaxies we combine observations of CO (HERACLES), HI (THINGS), IR (SINGS), and UV (GALEX) to study how the ISM forms stars in regions of low molecular gas surface density. The gasto-stars conversion appears to be a two step process: 1) the formation of dense (molecular) gas from the (atomic) ISM and 2) the formation of stars from that dense phase. Distinguishing these processes requires obtaining high-significance measurements of molecular gas in low surface brightness, HIdominated regions. We do this using a novel technique, leveraging HI velocity fields from THINGS and wide area coverage of HERACLES to stack CO spectra out to the optical radius. We find CO to decrease uniformly over all radii and scale remarkably linearly with tracers of star formation (IR and FUV). The H2-SFR relation is linear for individual galaxies and does not appear to depend on local gas surface density. However, we find systematic offsets between galaxies which dominate the scatter of the combined relation. Meanwhile, the H2-to-HI ratio varies by several orders of magnitude with radius and total gas surface density and, therefore, sensitively regulates the supply of star-forming molecular gas.

133.05

The Life and Death of Dense Molecular Clumps Around Massive YSOs in the LMC

Jonathan P. Seale¹, L. W. Looney², T. Wong², J. Ott³

¹Space Telescope Science Institute, ²University of Illinois, ³National Radio Astronomy Observaory. 3:10 PM - 3:20 PM

Room 4C-4

We present observations of the dense molecular clumps toward active star formation regions N105, N113, N159, and N44 in the LMC. Observations were performed with the Australia Telescope Compact Array in the 3 mm transitions of HCO+ and HCN. The observations reveal that the molecular material is clumpy, with individual clump masses between 10^2 and 10^4 solar masses and radii of <1 pc to ~2 pc. While many of the clumps are coincident with tracers of star formation, we find several to be devoid of any star formation signposts. The clumps with on-going star formation are on average 3-5 times more massive than those without, suggesting that the mass of the most massive star a clump forms may be determined by the mass of the natal clump. Moreover, we find a possible correlation between the mass of a clump and the projected distance between the clump's center and the forming star, suggesting that as a massive star forms, it becomes displaced from the clump's emission peak as it dissipates a significant fraction (>1/2) of the surrounding clump. We also find a number of YSOs within the imaged regions that are not associated with HCO+ or HCN emission; these YSOs have presumably destroyed their natal clumps to become evolutionarily older than those in clumps. The strength of the 10 micron silicate absorption feature seen in mid-IR spectra of YSOs is correlated with a source's association with a molecular clump; objects within clumps have deep silicate features, while those outside clumps have features that are weak or non-existent. This correlation suggests the silicate feature is formed by material on clump-sized scales. Using a large sample of LMC massive YSO spectra, we estimate that $^{\circ}60\%$ of the YSOs detected in the LMC via their mid-IR emission are no longer located in molecular clumps.

Monday, January 10, 2011, 3:40 PM - 4:30 PM 134

Pierce Prize: Dark Matter and Black Holes Over Cosmic Time Invited Session *Ballroom 6AB*

134.01 Dark Matter and Black Holes Over Cosmic Time Tommaso Treu¹ ¹University of California.

Ballroom 6AB

The standard cosmological model successfully reproduces the properties of the universe on supergalactic scales. However, it is unclear whether it can match the detailed properties of galaxies themselves. In particular, the origin of spheroidal galaxies is currently a point of discord between observation and the standard hierarchical model. For example, the stellar populations properties and sizes of massive galaxies are difficult to reproduce by models. Surprisingly, in the past decade it has become clear that supermassive black holes might be an essential ingredient to solve this puzzle: they

are found ubiquitously at the center of spheroidal galaxies and their mass correlates with global properties of the host. Furthermore my work, and that of others, has shown that global properties of spheroidal galaxies also correlate very tightly with those of their dark matter halos. A unified description of dark matter, baryons and black holes seems thus necessary to explain the observed correlations, and could perhaps reconcile the standard model with the conflicting observations. I will present highlights of my observational research program aimed at measuring the evolution over cosmic time of black holes, stars, and dark matter in spheroidal galaxies.

Monday, January 10, 2011, 4:30 PM - 5:20 PM 135 Evonlanets: Micalianed Migratory Metallic and Mini

Exoplanets: Misaligned, Migratory, Metallic, and Mini Invited Session *Ballroom 6AB*

135.01

Exoplanets: Misaligned, Migratory, Metallic, and Mini Geoffrey W. \mbox{Marcy}^1

¹UC, Berkeley.

Ballroom 6AB

The past year saw paradigms challenged and long-sought domains detected from Doppler, transit, microlensing, and direct imaging observations of exoplanets. The tilt of orbital planes with respect to stellar equators has been studied in over 30 planetary systems. Shockingly, they are not generally aligned, including some orbits quite tilted relative to the star's equator and a few even retrograde. These misalignments utterly contradict the accepted theory of planet migration in a gaseous protoplanetary disk, and they differ from the co-planar orbits in our own solar system. Equally puzzling, many close-in gas giants display grossly inflated radii, temperature inversions of mysterious origin, and non-equilibrium abundances of CO and methane. Meanwhile, Doppler-detected exoplanets reveal, for the first time, a rapidly rising mass function toward lower masses - all the way to 3 Earth-masses, pointing to the occurrence frequency of Earth-mass planets. The NASA Kepler Mission has discovered over 700 candidate planets, with most having diameters less than 5 times that of Earth and some as small as that of Earth. One planet has a radius, mass, and density in a new domain having no counterpart in our Solar System, opening a new chapter in planetary science. The mutual inclinations and gravitational interactions among planets measured by Kepler provide key information on the formation and evolution of planetary systems. The diversity of exoplanets continues to confound, delight, and inform us about planetary systems in general, with our Solar System being just one example.

Tuesday, January 11, 2011, 8:30 AM - 9:20 AM 200 The Virgo Cluster: New Results from New Surveys Invited Session Ballroom 6AB

200.01 The Virgo Cluster: New Results from New Surveys Laura Ferrarese¹

¹*Herzberg Institute of Astrophysics, Canada. Ballroom 6AB*

The Virgo Cluster contains about two thousand of cataloged galaxies orbiting within a dark halo of roughly 400 trillion solar masses. It is the most thoroughly studied cluster in the universe and has long played a key role in our understanding of how galaxies form and evolve in dense environments. At a distance of 16.5 Mpc, it also occupies a unique position in galaxy and cluster research, offering a local counterpart to the massive clusters studied at high redshift, while at the same time allowing astronomers to study analogs of the faint, low surface brightness galaxies of the Local Group in a different environment, and in far greater numbers. During recent years, several new surveys of the Virgo Cluster have been undertaken at wavelengths ranging from the x-ray to the radio. In this talk, I will briefly review these surveys and summarize some of their scientific highlights, focusing closely on what observations of the Virgo Cluster have taught us about the role of environment in galaxy evolution.

Tuesday, January 11, 2011, 9:00 AM - 6:30 PM 239 *Dark Energy Survey* Poster Session

Exhibit Hall

239.01

DECam Prototype Observations for Calibration of the Dark Energy Survey

Kyler Kuehn¹, Dark Energy Survey Collaboration ¹*Argonne National Laboratory.*

Exhibit Hall

The Dark Energy Survey (DES) makes use of the Dark Energy Camera (DECam) to survey approximately 1/4 of the southern sky in order to observe supernovae, galaxy clusters, baryon acoustic oscillations, and weak gravitational lensing, with the ultimate goal of obtaining unprecedented constraints on the Dark Energy Equation of State. A Prototype Dark Energy Camera (PreCam) has been fully operational since September 2010, more than a year prior to the start of DES. It serves not only as a testbed for DECam hardware and software, but also as a means to make standard star calibration measurements throughout the proposed DES footprint. We describe the current status of the PreCam observations, as well as its calibration goals and expected contribution to the overall scientific output of DES.

239.02 The Dark Energy Survey Camera (DECam) and Upgrade (DESpec) H. Thomas Diehl¹

¹Fermi National Accelerator Laboratory.

Exhibit Hall

The Dark Energy Survey (DES) is a next generation optical survey aimed at understanding the expansion rate of the universe using four complementary methods: weak gravitational lensing, galaxy cluster counts, baryon acoustic oscillations, and Type Ia supernovae. To perform the survey, the DES Collaboration is building the Dark Energy Camera (DECam), a 3 square degree, 520 Megapixel CCD camera that will be mounted at the prime focus of the Blanco 4-meter telescope at the Cerro Tololo Inter-American Observatory. CCD production has finished, yielding roughly twice the required 62 2kx4k detectors. The construction of DECam is nearly finished; some components have already been received at CTIO. In addition, the DES Collaboration has been evaluating the physics prospects and design options of the Dark Energy Survey Upgrade, for which the instrument is a multi-fiber spectrometer, called DESpec. This poster will concentrate on the present status of DECam and the expected start of survey operations and show initial concepts for DESpec.

239.03

The Dark Energy Camera Data Acquisition and Control System

Elizabeth J. Buckley-Geer¹, J. Annis¹, M. Bonati², J. Eiting³, A. Elliot³, M. Haney⁴, W. Hanlon⁴, K. Honscheid³, I. Karliner⁴, K. W. Kuehn⁵, S. E. Kuhlmann⁵, S. Marshall⁶, A. J. Roodman⁶, T. Schalk⁷, G. Schumacher², J. Thaler⁴, W. Wester¹

¹Fermi Nat'l Accelerator Laboratory, ²Cerro Tololo Inter-American Observatory, Chile, ³The Ohio State University, ⁴University of Illinois (Urbana-Champaign), ⁵Argonne National Laboratory, ⁶SLAC National Accelerator Laboratory, ⁷University of California, Santa Cruz.

Exhibit Hall

The Dark Energy Camera (DECam) data acquisition and control system is called the Survey Image System Process Integration (SISPI). Implemented as a distributed multi-processor system, SISPI consists of a set of processes that will coordinate and perform image acquisition and deliver images to the data management system for processing. Separate processes for instrument control, image building and analysis, image acquisition and observatory control are built on top of an infrastructure layer that provides message passing and communications. Additional system components include a flexible configuration system and the facility database. The command protocol is implemented in Python using a client-server design pattern derived from the SML and SCLN communications software developed at CTIO. A publish-subscribe model has been added to support the distribution of telemetry data and alarm messages. The design of the graphical user interfaces follows the Model-View-Controller approach to distinguish between the actual information and the graphical representation of the data. We will present the software architecture of the SISPI system and report on the current status of the project.

Calibration Of The Dark Energy Survey Camera: Measurements Of Focal Plane Flatness And Crosstalk Among CCDs

Marcelle Soares-Santos¹, J. Hao¹, J. Estrada¹, E. Buckley-Geer¹, H. Cease¹, G. Derylo¹, H. T. Diehl¹, B. Flaugher¹, R. Flores¹, K. Honscheid², I. Karliner³, D. Kubik¹, K. Kuk¹, N. Kuropatkin¹, H. Lin¹, A. Lathrop¹, J. Montes¹, V. Scarpine¹, K. Schultz¹, L. Scott¹, T. Shaw¹, W. Stuermer¹, W. Wester¹, Dark Energy Survey ¹Fermi National Accelerator Laboratory, ²Ohio State University, ³University of Illinois. Exhibit Hall

DECam is an extremely red sensitive 520 Megapixel camera designed for the incoming Dark Energy Survey (DES). It is consist of sixty two 4k x 2k and twelve 2k x 2k 250-micron thick fully-depleted CCDs, with a focal plane of 44 cm in diameter and a field of view of 2.2 square degree. It will be attached to the Blanco 4-meter telescope at CTIO. The DES will cover 5000 square-degrees of the southern galactic cap in 5 color bands (g, r, i, z, Y) in 5 years starting from 2011. We present our techniques for measuring the flatness of the focal plane and the crosstalk among CCDs for theDECam. We developed an image based technique to measure the flatness by moving and matching a projected grid pattern across the focal plane. The flatness is then determined by the variation of the grid pattern. We measure the crosstalk by shotting laser spots on every CCD and look at the crosstalk on other CCDs. The results show the crosstalk are well within the DES specification.

240

Radio Sky Surveys Project with the Allen Telescope Array Poster Session *Exhibit Hall*

240.01

Spectropolarimetry with the Allen Telescope Array: Revealing a New Dimension

Casey J. Law¹, B. M. Gaensler², G. C. Bower¹, Allen Telescope Array Team ¹*Radio Astronomy Lab, UC Berkeley,* ²*University of Sydney, Australia. Exhibit Hall*

We present a novel analysis of the Faraday rotation properties of 37 bright, polarized radio sources. Observations with the Allen Telescope Array (ATA) cover frequencies from 1 to 2 GHz, which is sensitive to a range of Faraday rotation effects. We use RM synthesis to make the first detection of multiple RM components towards individual sources. Typically, these complexities in Faraday rotation have been treated as anomalies, but this technique reveals the true complexity of this process. Roughly a quarter of the sources studied have extra RM components with high confidence (brighter than \approx 40 mJy), when observing with a RM resolution of roughly 100 rad m⁻². We show that the peak RM cannot be determined more precisely than the RM beam size, but that the RMs from this work are consistent with that of earlier, narrow-bandwidth, all-sky surveys. This work also describes the polarimetry calibration procedure and that on-axis ATA observations of linear polarization can be calibrated to an accuracy of 0.2% of Stokes I. Future research directions include studying the time-dependent RM structure in Active Galactic Nuclei (AGNs) and enabling accurate, wide-area RM surveys to test models of Galactic and extragalactic magnetic fields.

240.02 **The Variable Radio Sky from the Allen Telescope Array Steve Croft**¹, G. C. Bower¹, Allen Telescope Array Team

¹UC Berkeley.

Exhibit Hall

The Allen Telescope Array (ATA) is, among other projects, undertaking large surveys of the radio sky at 1.4 and 3.14 GHz. With its wide field of view (about 5 square degrees at 1.4 GHz), the ATA is one of the most powerful radio survey telescopes in the world. As well as quantifying variability of radio sources using many epochs of imaging, and exploring new areas of area -- depth -- cadence parameter space in the search for radio transients, we are undertaking multi-wavelength studies (e.g. simultaneous optical observations of nearby galaxy nuclei using the Kepler satellite) to better probe the physical processes driving variability.

240.03

Search for Electrostatic Discharges on Mars

Imke de Pater¹, M. Anderson¹, A. Siemion¹, D. Wertheimer¹, G. C. Bower¹, W. C. Barott¹, Allen Telescope Array Team

¹UC, Berkeley.

Exhibit Hall

The Allen Telescope Array was used to monitor Mars between March 8 and June 1, 2010 over a total of approximately 42 hours, for signals indicative of electrostatic discharge using a wideband signal processor developed at the Center for Astronomy Signal Processing and Electronics Research (CASPER), following the report by Ruf et al., 2009, of the possible detection of electrostatic discharge on Mars. In conjunction with the ATA, simultaneous observations were done by JPL on the Deep Space Network antenna.

The 1024-channel spectrometer receives complex-baseband voltage data from the ATA beamformer, from which it computes power and spectral kurtosis of the input signal in real-time. For this experiment, the ATA beamformers, each of which delivers a 104.8 MHz bandwidth, were tuned to 3.2 and 8.0 GHz. The spectral kurtosis is calculated using the method suggested in Nita et al., 2007, using a ratio between power and power squared. Variations in the kurtosis are indicative of non-Gaussianity in the signal, which can be used to detect variable cosmic signals as well as radio frequency interference -- in particular, lightning discharge in the Martian atmosphere measurable as a variation in the kurtosis takes on a constant value. Interference, and the non-thermal emission associated with electrostatic discharge, are non-Gaussian, and thus cause the kurtosis to deviate from the Gaussian value.

The instrument and analysis were tested on a variety of known sources of non-Gaussian emission, including the Crab pulsar and a number of terrestrial sources, such as satellites, which showed appropriate deviations in power and kurtosis corresponding to radio interference, and in the case of the Crab pulsar, giant pulses.

240.04

Pulsar Observations with the Allen Telescope Array

Gregory Desvignes¹, Allen Telescope Array Team

¹University of California Berkeley.

Exhibit Hall

The detection of the gravitational wave background from massive black holes mergers requires to precisely monitor an array of millisecond pulsars spread throughout the Galaxy.

To achieve high precision pulsar timing of millisecond pulsars, high time resolution and wide bandwidth

are required. The effects of the interstellar medium have also to be taken into account. We report here the installation of a new real-time coherent dedispersion backend at the Allen Telescope Array (ATA) in the aim of monitoring a set of strong millisecond pulsar. Currently three beamformers can provide a 72 MHz bandwidth, among two of them have independent and tunable Intermediate Frequency bands. The unique capability of the ATA to simultaneously observe pulsars at two widely spaced frequencies will contribute to a better understanding of the effects of the interstellar medium on pulsar timing.

240.05

setiQuest: Leaving the Cathedral and Embracing the Bazaar

Jill C. Tarter¹, A. Agrawal¹, ATA SonATA Team

¹SETI Inst..

Exhibit Hall

We are building the **setiQuest** open community to involve the world in five different threads of a SETI program on the ATA. setiObs are the routine observations at the ATA, that will be the beneficiary of the other four setiQuest threads, with the resultant improvement in search speed and expansion of the classes of signals that can be detected during targeted star searches and surveys. setiCode involves publishing and improving our current SonATA code base as an open source project. setiData is a weekly program to capture, and make available through Amazon Web Services, several hours of raw data recorded from the output of one of the beamformers at the ATA. These data can be used by the community for analyses and testing of new signal processing algorithms for complex, noise-like signals with a large number of degrees of freedom, or improved algorithms for the types of narrowband, continuous or pulsed signals already identified by SonATA. setiCloud is a stack built by Cloudant, Inc. that allows access to computational and storage resources available in the Amazon Cloud for setiQuest use. setiCitizen is our attempt to use the pattern recognition capabilities of the human brain coupled with visual (and perhaps auditory) sensors to quickly find signals in noise. The intent of this citizen science project is to allow crowdsourcing signal detection in certain portions of the terrestrial microwave window that contain so many signals that SonATA cannot now complete its detection and classification tasks within the required near-real-time constraint. Patterns indicating signals that have been validated and screened against known interference will be scheduled for automatic follow up observations. The setiQuest community is being encouraged to help with the development of the tools needed for these five threads as well as utilizing the end products.

240.06

Results from the Fly's Eye Fast Radio Transient Search at the Allen Telescope Array

Andrew Siemion¹, G. Bower¹, M. Dexter¹, G. Foster², W. Mallard¹, P. McMahon³, M. Wagner¹, D. Werthimer¹, Allen Telescope Array Team

¹University of California, Berkeley, ²Oxford University, United Kingdom, ³Stanford University. Exhibit Hall

The relatively unexplored fast radio transient parameter space is known to be home to a variety of interesting sources, including rotating radio transients (RRATs), γ -ray burst (GRB) afterglows and pulsar giant pulses. In addition, a variety of hypothesized but as yet unobserved phenomena, such as primordial black hole evap- oration (Rees, 1977), prompt emission associated with coalescing massive objects (Hansen & Lyutikov, 2008) and hyper-flares from magnetars (Popov & Postnov, 2007) have been suggested. The announcement by Lorimer et al. of the detection of a powerful (~30 Jy) and highly dispersed (DM ~ 375 pc cm–3) radio pulse in Parkes multi-beam survey data (Lorimer et al., 2007), and subsequent consternation, have demonstrated both the potential utility of bright radio pulses as probes of the ISM and IGM, as well as the need for wide-field surveys characterizing the fast radio transient

population.

We present results from the 450-hour Fly's Eye survey for powerful dispersed radio pulses at the Allen Telescope Array (ATA). The Fly's Eye spectrometer processes 44 independent signal paths, each with a bandwidth of 209 MHz centered at 1420 MHz, and produces 128-channel power spectra accumulated for 0.6ms. Independent antenna-pointings of the extant 42-dish ATA yields a maximum total field-of-view of approximately 198 square degrees.

240.07

Coordinated Radio and High-Energy Observations of Cygnus X-3 with the Allen Telescope Array Deter K. G. Williams¹, C. G. Bouwer¹, J. A. Temsiek¹, Allen Telescope Array Team

Peter K. G. Williams¹, G. C. Bower¹, J. A. Tomsick¹, Allen Telescope Array Team

¹UC Berkeley.

Exhibit Hall

The microquasar Cygnus X-3 is one of the few Galactic sources known to produce relativistic jets and can be one of the brightest radio sources in the Galaxy when flaring. In late 2009 it became the first such system to be seen in the gamma-ray regime with detections by both AGILE and *Fermi*. We have observed Cyg X-3 at 3 GHz every ~5 days for the past six months with the Allen Telescope Array in conjunction with space-based X-ray (INTEGRAL, RXTE) and gamma-ray (*Fermi*) observations. We present results from both the long-term dataset and intensive observing sessions in which we obtain the radio lightcurve of Cyg X-3 on ~10-minute timescales. We focus particularly on a May 2010 minor flare event for which we have coverage in all three bands.The first phase of the ATA was funded through generous grants from the Paul G. Allen Family Foundation. UC Berkeley, the SETI Institute, the National Science Foundation (Grant No. 0540599), Sun Microsystems, Xilinx, Nathan Myhrvold, Greg Papadopoulos, and other corporations and individual donors contributed additional funding.

241 *The Milky Way, The Galactic Center* Poster Session *Exhibit Hall*

241.01

The GALFA-HI Survey: Feeding the Disk via Stellar Feedback

Mary E. Putman¹, J. Peek¹, D. Saul¹, J. Grcevich¹, A. Begum², K. Douglas³, S. Gibson⁴, C. Heiles⁵, E. Korpela⁵, M. Lee², S. Stanimirovic²

¹Columbia University, ²UW-Madison, ³University of Exeter, United Kingdom, ⁴Western Kentucky University, ⁵UC-Berkeley.

Exhibit Hall

The contribution of future star formation fuel to a galaxy from evolved stars remains uncertain. We present a correlation of discrete clouds of HI gas with evolved variable stars and find a number of cases where stellar mass-loss is likely to have created the cloud. The results of this study impact our understanding of both stellar outflows and galactic gas recycling. This research was partially funded by NSF grant AST-0917810.

The GALFA-HI Survey: Transition from HI to H2 Caught in Action in the Perseus Molecular Cloud Min-Young Lee¹, S. Stanimirovic¹, A. Leroy², K. Douglas³, J. Di Francesco⁴, S. Gibson⁵, L. Knee⁶, R. Plume⁷, A. Begum¹, J. Grcevich⁸, C. Heiles⁹, E. Korpela⁹, J. Peek⁸, N. Pingel¹, M. Putman⁸, D. Saul⁸ ¹University of Wisconsin-Madison, ²NRAO, ³University of Exeter, United Kingdom, ⁴Herzberg Institute of Astrophysics, Canada, ⁵Western Kentucky University, ⁶Atacama Large Millimeter Array, Chile, ⁷University of Calgary, Canada, ⁸Columbia University, ⁹University of California-Berkeley. Exhibit Hall

The conversion of atomic gas into molecular gas is a critical process for star formation. Yet, a deep understanding of fundamental agents that control the ratio of atomic to molecular gas in molecular clouds has not been achieved.

Recently, Krumholz et al. (2009) provided theoretical predictions for the ratio of atomic to molecular gas in galaxies as a function of galactic properties (total gas column density and metallicity). We test the Krumholz's predictions on sub-parsec scales by investigating the ratio of atomic to molecular gas across the Perseus molecular cloud. We estimate the dust column density using the IRIS 60 and 100 micron maps and derive the H2 column density from the excess of infrared emission relative to the HI column density. Using the HI data from the GALFA-HI Survey, we derive the map of R_{H2} (H2 surface density / HI surface density) for Perseus. Our comparison of observational data with the Krumholz's predictions shows that the model reasonably well describes R_{H2} as a function of total gas column density even at sub-parsec scales. We compare R_{H2} for several star-forming and dark clouds in Perseus to investigate the role of interstellar radiation field in molecule formation.

This research was partially funded by the NSF grant

AST-0707679 and the Research Corporation for Science Advancement.

241.03

The GALFA-HI Survey: Extracting New Clouds From a Complex Medium

Destry R. Saul¹, J. E. G. Peek¹, J. Grcevich¹, M. E. Putman¹, C. Heiles², S. Stanimrovic³, E. J. Korpela⁴, K. A. Douglas⁵, M. Lee³, S. J. Gibson⁶, A. Begum³, A. R. H. Brown¹, B. Burkhart³, E. T. Hamden¹, N. M. Pingel³, S. Tonnesen¹

¹Columbia University, ²UC Berkeley, ³University of Wisconsin, ⁴Space Sciences Laboratory, UC Berkeley, ⁵University of Exeter, United Kingdom, ⁶Western Kentucky University.

Exhibit Hall

We present a new catalog of compact, isolated neutral hydrogen clouds extracted from the first GALFA-HI data release.

With ~4' spatial resolution, 0.18 km/s spectral resolution, and a 80mK noise level per 1 km/s channel, the GALFA-HI survey provides a new view of neutral Galactic hydrogen. To identify isolated clouds, we developed a new algorithm based on a difference of gaussians wavelet. Our algorithm was tuned to specifically search for clouds smaller than 20', velocity widths of less than 20 km/s, and with absolute velocities less than 700 km/s. Thousands of clouds were detected. These may be new dwarf galaxies, high velocity clouds, disk-halo clouds, or some other exotic object. We will highlight the distribution and other properties of this new population and explain our methods in detail. This research was partially funded by NSF grant AST-0917810.

241.04

The GALFA-HI Survey: From Pretty Images To Quantifying Interstellar Inhomogeneities Snezana Stanimirovic¹, A. Begum¹, K. A. Douglas², S. J. Gibson³, J. Grcevich⁴, C. Heiles⁵, M. Lee¹, E. J. Korpela⁵, J. Peek⁴, M. Putman⁴, N. M. Pingel¹, D. Saul⁴ ¹UW-Madison, ²Univ. of Exeter, United Kingdom, ³Western Kentucky University, ⁴Columbia University, ⁵UC-Berkeley.

Exhibit Hall

Understanding the origin and nature of interstellar inhomogeneities in galaxies is a crucial step toward inclusion of realistic high-density regions in numerical simulations. Yet, driving sources and modes of interstellar turbulence -- an important ingredient for formation and evolution of interstellar structure -- have largely been unexplored even in the Galaxy.

We use data products from the GALFA-HI survey in conjunction with results from recent numerical simulations to study the level of interstellar turbulence and make connections with the dominant underlying energy sources across different Galactic environments. The GALFA-HI survey has been mapping the Galactic neutral hydrogen (HI) distribution using the the Arecibo Observatory, the largest single-dish radio telescope in the world. The unsurpassed combination of sensitivity, resolution, and mapping speed of this survey result in stunning images of the Galaxy with high spatial and velocity dynamic range perfectly suited for studying the origin and nature of interstellar inhomogeneities. This research was partially funded by the NSF grant

AST-0707679 and the Research Corporation for Science Advancement.

241.05

The GALFA-HI Survey: Probing the Anatomy of Galactic Neutral Hydrogen Nickolas Pingel¹

¹University of Wisconsin-Madison.

Exhibit Hall

The Galactic HI survey with the Arecibo L-band Feed Array (GALFA-HI) is observing the whole Arecibo sky (about 13,000 square degrees), with high angular (3.5 arcmin) and velocity resolution (0.2 km s-1). The unprecedented angular and velocity resolution allow studies of the Galactic gaseous disk, halo, and the flow of material between them. The survey operates mainly commensally with other ALFA surveys, saving thousands of hours of telescope time.

The 7-beam feed array ALFA is tuned to the hyperfine transition of HI at 1420.405 MHz, and a specially developed method the Least-Squares Frequency Switching is used for bandpass fitting.

The survey uses a combination of basket-weave and drift observing modes,

and the final data products are in the form of RA x Dec x Velocity data cubes.

From these cubes we can create detailed images of the Galactic HI, and other galaxies. The reduced data are released publicly at http://sites.google.com/site/galfahi/data. We present the current survey and data release status and examples of GALFA-HI images in different visualization modes.

This research was partially funded by the NSF grant[[Unsupported Character -
]]AST-0707679 and the Research Corporation for Science Advancement.

N. Pingel1, S. Stanimirovic, A. Begum1, K. A. Douglas2, S. J. Gibson3, J. Grcevich4, C. Heiles5, M. Lee1, E. J. Korpela5, J. Peek4, M. Putman4, D. Saul4

1UW-Madison, 2Univ. of Exeter, United Kingdom, 3Western Kentucky University, 4Columbia University, 5UC-Berkeley.

The GALFA-HI Survey: Searching for Undiscovered Local Group Dwarf Galaxies with HI

Jana Grcevich¹, D. Saul¹, J. E. G. Peek¹, M. Putman¹, A. Begum², K. Douglas³, S. J. Gibson⁴, C. Heiles⁵, E. J. Korpela⁵, M. Lee², S. Stanimirovic²

¹Columbia University, ²University of Wisconsin, ³University of Exeter, United Kingdom, ⁴Western Kentucky University, ⁵University of California.

Exhibit Hall

We present a list of candidates for previously undiscovered dwarf galaxies selected from a catalog of compact, isolated neutral hydrogen clouds identified in the GALFA-HI survey (Saul et al. 2010, in prep.). Clouds were scored based on how well their observational characteristics matched those of known Local Group dwarf galaxies, and in particular the characteristics of the only known ultra-faint galaxy to contain HI, Leo T. Follow-up observations will be conducted for the highest scoring dwarf candidates to determine if an associated stellar population exists. This research was partially funded by NSF grants AST-0917810 and AST-0904059.

241.07

Multiwavelength Observations of the Most Massive Stellar Clusters in the Galaxy

Emily Richards¹, C. C. Lang¹, C. Trombley², D. F. Figer², HST/NICMOS GC Paschen Alpha Team ¹University of Iowa, ²Rochester Institute of Technology.

Exhibit Hall

The Galactic Center Arches and Quintuplet stellar clusters are two of the most luminous clusters in the Galaxy. These massive clusters produce high rates of ionizing photons and powerful winds which sculpt the surrounding interstellar medium (ISM) and form the Sickle and Arched Filaments HII regions. Recently, these clusters and HII regions have been studied in high resolution by Spitzer, Chandra and HST/NICMOS. Here we present a multiwavelength analysis of the interaction between the clusters and the ISM. Throughout the Galaxy, only a handful of similarly luminous and massive clusters are known. It is likely that other such clusters reside in our Galaxy but are obscured from optical detection. Using data from infrared and radio surveys, 40 candidate massive clusters have been identified. We have followed up on the interstellar environment of six candidate clusters using the VLA at 8.5 and 4.9 GHz. Parameters such as the Lyman continuum flux, electron density, and total ionized mass can be determined from these radio observations and can provide estimates of the stellar content in the candidate clusters. Finally, comparison between the radio and infrared (Spitzer) data will lead to a more complete understanding of the interaction between the stellar clusters and the ISM. This material is based upon work supported by the National Science Foundation under Grant Number 0907934. The authors also acknowledge support from the University of Iowa.

241.08

Small Scale Filamentation in the Galactic Center at 5 GHz: A VLA Survey

Jared Moon¹, C. C. Lang¹, J. Lazio²

¹University of Iowa, ²Jet Propulsion Lab.

Exhibit Hall

We present a survey of the central 200 pc of the Galactic Center made with the VLA at 5 GHz in total and polarized intensity. A catalog of extended and compact sources is presented. The main scientific aim is to determine whether numerous linear radio filamentary structures detected both here and previously (by Nord et al. 2004 and Yusef-Zadeh et al. 2004) are in fact non-thermal in nature. Detections of filaments in polarized intensity are shown as well as spectral indicies based on multifrequency data (a recent 1.4 GHz survey of this region by Lang et al. (2010)). Better understanding the nature of these non-thermal filaments provides important insight into the nature of the magnetic field in the Galactic Center.

Finally, we compare some of our 5 GHz sources to counterparts discovered in the HST/NICMOS Paschen Alpha Survey of the Galactic Center. This material is based upon work supported by the National Science Foundation under Grant No. 0907934.

241.09

The Shape and Profile of the Galactic Halo as Seen by CFHT LS/b>

Branimir Sesar¹, M. Juric², Z. Ivezic³

¹Caltech, ²Harvard Smithsonian Center for Astrophysics, ³University of Washington. Exhibit Hall

One of the key goals of Galactic structure studies is to map the distribution of stars in the Galaxy. We use Canada-France-Hawaii Telescope Legacy Survey (CFHTLS) data, recalibrated and transformed to the Sloan Digital Sky Survey ugri photometric system, to study the distribution of near-turnoff main sequence stars in the Galactic halo along four lines of sight and to distances of ~35 kpc from the Sun. We find that the halo number density profile becomes steeper at Galactocentric distances greater than $R_{gal} \sim 28$ kpc, with the power law index changing from $n_{inner} = -2.6$ to $n_{outer} = -3.8$. The oblateness of the halo is q = 0.70 and shows no evidence of change across the range of probed distances. The Sagittarius stream is detected in the I = 173 deg and b = -62 deg direction as an overdensity of [Fe/H] ~ -1.5 dex stars at $R_{gal} \sim 32$ kpc, and provides a new constraint for the Sagittarius stream and dark matter halo models. The Monoceros stream is also detected, as an overdensity of [Fe/H] > -1.5 dex stars in the I=232 deg and b = 26 deg direction with $R_{gal} < 25$ kpc. In two sightlines where we do not detect significant substructure, the median metallicity is found to be independent of distance within systematic uncertainties ([Fe/H] ~ -1.5 with 0.2 dex of uncertainty).

241.10

A Kinematic Asymmetry and Interaction with the Galactic Bar

Roberta M. Humphreys¹, T. C. Beers², J. E. Cabanela³, S. Grammer¹, J. A. Larsen⁴, Y. Lee² ¹Univ. of Minnesota, ²Michigan State University, ³Minnesota State University Moorhead, ⁴U.S. Naval Academy.

Exhibit Hall

The Thick Disk and Inner Halo stars in Quadrant I (Q1) have a significant over-density or star count excess compared to similar stars in the complementary fields in Quadrant 4 which extend to 5 kpc along the line of sight. The Thick Disk stars in Q1 have a much slower effective rotation rate compared to the corresponding Q4 stars (Parker et al 2004). We have greatly expanded the kinematic data with radial velocities and derived metallicity parameters for over 4000 stars. We confirm the corresponding kinematic asymmetry, extended to greater distances and with more spatial coverage. The Thick Disk stars in Q1 have a rotational lag of 60 -- 70 km/s relative to circular rotation, and the Metal-Weak Thick Disk stars have an even greater lag of 100 km s. Both lag their corresponding populations in Q4 by approximately 30 km/s. Interestingly, the Disk stars in Q1 also appear to participate in the rotational lag by about 30 km/s. The enhanced rotational lag for the Thick Disk in Q1 extends to 4 kpc or more from the Sun. At 3 to 4 kpc, our sight lines extend above the density contours on the near side of the bar, and as our lines of sight pass directly over the bar the rotational lag appears to decrease. This is consistent with a ``gravitational wake"induced by the rotating bar in the Disk which would trap and pile up stars behind it. We conclude that a dynamical interaction with the stellar bar is the most probable explanation for the observed kinematic and spatial asymmetries. This work was supported by the National Science Foundation.

The Genesis of the Milky Way's Thick Disk via Stellar Migration

Sarah Loebman¹, R. Roskar¹, V. P. Debattista², Z. Ivezic¹, T. R. Quinn¹, J. Wadsley³ ¹University of Washington, ²Jeremiah Horrocks Institute, University of Lancashire, United Kingdom, ³McMaster University, Canada.

Exhibit Hall

The separation of the Milky Way disk into a thin and thick component is supported by differences in kinematics and metallicity. These differences have lead to the predominant view that the thick disk formed early via a cataclysmic event and constitutes fossil evidence of the hierarchical growth of the Milky Way. We show here, using N-body simulations, how a double vertical structure, with stellar populations displaying similar dichotomies can arise purely through internal evolution. Stars migrate radially, while retaining nearly circular orbits, as described by Sellwood & Binney (2002). As stars move outwards their vertical motions carry them to larger heights above the mid-plane, populating a thickened component. Such stars found at present time in the solar neighborhood formed early in the disk's history at smaller radii where stars are more metal-poor and α -enhanced, leading to exactly the properties observed for thick disk stars. Classifying stars as members of the thin or thick disk by either velocity or metallicity leads to an apparent separation in the other property as observed. This scenario is supported by the SDSS observation that stars in the transition region do not show any correlation between rotation and metallicity. Such a correlation is present in young stars and arises because of epicyclic motions but migration radially mixes stars, washing out the correlation. Using the Geneva Copenhagen Survey, we indeed find a velocity-metallicity correlation in the younger stars and none in the older stars. We predict a similar result when separating stars by $[\alpha/Fe]$. The good qualitative agreement between our simulation and observations are remarkable because the simulation was not tuned to reproduce the Milky Way, hinting that the thick disk may be dominated by stellar migration. Nonetheless, we cannot exclude that some fraction of the thick disk is a fossil of a past more violent history.

241.12

The Bulge Radial Velocity Assay: New Observations and Results

Andrea M. Kunder¹, R. de Propris¹, M. Rich², A. Koch³, C. Howard⁴, C. I. Johnson², W. Clarkson², R. Mallery², J. Kormendy⁵, A. C. Robin⁶, R. Fux⁷, R. B. David², H. Zhao⁸, K. Kuijken⁹, A. Pipino¹⁰, J. Shen⁵ ¹Cerro Tololo Inter-American Observatory, Chile, ²UCLA, ³Cerro Tololo Inter-American Observatory, Netherlands, ⁴NASA Ames Research Center, ⁵University of Texas at Austin, ⁶Observatoire de Besancon, Institut Utinam, France, ⁷Observatoire de Geneve, Universite de Geneve, Switzerland, ⁸University of St. Andrews, United Kingdom, ⁹University of Leicester, Netherlands, ¹⁰ETH Zurich, Switzerland. Exhibit Hall

The Bulge Radial Velocity Assay (BRAVA) is a large scale spectroscopic survey of the stellar radial velocities of M-type giants whose population membership in the bulge is well established. To date, ~4500 radial velocities from the CTIO 4m Hydra multi-object spectrograph have been obtained. Here we discuss ~4500 additional radial velocity observations taken to sample the kinematics the bulge major axis at -10<l<+10 and b=-6,-8. These velocities are used to constrain dynamical models of the bulge and to investigate any possible cold stellar streams in the bulge and its vicinity. Comparison of the data to current models shows disagreement with either predicted rotation, predicted dispersion, or both, and shall be discussed.

Depletion of Giant Stars in the Galactic Nucleus due to a Top Heavy Mass Function

Mackenzie L. Jones¹, B. W. Murphy¹, K. A. Phifer¹, B. B. Geiss¹, M. J. McFall¹, H. N. Cohn² ¹Butler University, ²Indiana University.

Exhibit Hall

Using the direct Fokker-Planck method we have studied the effect of a top-heavy mass function on the depletion of post-main sequence stars in the Galactic Nucleus. Beginning with the standard Kroupa mass function, with stellar masses ranging from 0.1 to 50 solar masses, we ran a series of models with progressively flatter IMF slopes. Our top-heavy mass function had an approximate power-law slope of 2, with the Salpeter IMF slope being -1.35. With this top-heavy mass function, black holes outnumbered lower main sequence stars by a factor of 1000. We found that despite a top-heavy IMF, post-main sequence stars kept the same homologous profiles and underwent no more depletion than the standard Kroupa IMF. This implies that the most likely scenario for post-main sequence depletion is not pre-emptive destruction of main sequence stars by stellar mass black holes, but rather tidal disruptions due to the central supermassive black hole as found by Geiss et al. (2009). This project was funded in part by a grant from the Butler Institute for Research and Scholarship.

241.14

GLIMPSE360: Mapping the Galaxy's "Edge"

Robert A. Benjamin¹, B. Whitney², M. Meade², B. Babler², C. Watson³, E. Churchwell², GLIMPSE360 team ¹Univ. of Wisconsin, Whitewater, ²U. of Wisconsin-Madison, ³Manchester College. Exhibit Hall

We present compelling new evidence for the "truncation" of the Galactic stellar disk at R=13.4 ±0.4 kpc using data from the Spitzer Space Telescope's Warm Mission program GLIMPSE 360, a mid-infrared survey at 3.6 and 4.5 microns of the outer Galactic disk and warp, from galactic longitude l=65 to 265 degrees. The truncation is detected as a drop-off in the number of red giant stars per square degree fainter than a certain magnitude. Our average truncation distance is in excellent agreement with previous measurements of the truncation distance. By mapping the changing apparent magnitude of the dropoff as a function of Galactic longtiude, we are able to determine, for the first time, the variation in the truncation radius as a function of Galactic azimuth. Using TRILEGAL models of Galactic starcounts, we also constrain whether there is a sharp or more gradual dropoff in the density of the Galactic stellar disk beyond the truncation radius. This research was supported by NASA/JPL contract 1368014 and NASA ATP grant NNX10AI70G to the University of Wisconsin-Whitewater.

241.15

Galactic Plane Infrared Polarization Survey (GPIPS): Large-area B-field maps

Dan P. Clemens¹, A. Pinnick¹, M. Pavel¹, B. Taylor¹, J. Moreau¹, M. Bartlett¹, R. Marchwinski¹ ¹Boston Univ..

Exhibit Hall

The Galactic Plane Infrared Polarization Survey (GPIPS) is nearing completion on the 1.83m Perkins telescope outside Flagstaff, Arizona using the Mimir instrument configured as a near-infrared imaging polarimeter. The 10x10 arcmin field of view captures H-band (1.6 um) images of thousands of stars in every image, with about 150-300 stars in each field being bright enough for polarimetric analysis. GPIPS comprises 3,226 of these overlapping fields, covering 76 square degrees in the midplane (b to +/- 1 deg.) of the first Galactic quadrant.

GPIPS is now 72% completed and will release science-quality data to the community this spring. Over the past year, data processing pipelines have reached a stable maturity and calibration of instrumental polarization across the field of view has been achieved. Examples of fully calibrated, large-scale polarization maps that delineate the plane-of-sky magnetic field directions will be presented at this poster for fields containing diffuse ISM, infrared dark clouds, infrared stellar clusters, and stellar bubbles. Additionally, the set of data quantities to be contained in the release data will be presented and available for discussion and modification, based on community input. The polarization maps are spectacular - come take a look.

Supported by NSF grant AST 09-07790

241.16

Glimpse360: Observing The Outback Of The Galaxy

Barbara Whitney¹, R. Benjamin², M. Meade³, B. Babler³, C. Watson⁴, E. Churchwell³, T. Robitaille⁵, R. Indebetouw⁶, GLIMPSE360 Team

¹Space Science Institute & University of Wisconsin, ²University of Wisconsin-Whitewater, ³University of Wisconsin, ⁴Manchester College, ⁵Harvard-Smithsonian Center for Astrophysics, ⁶University of Virginia. Exhibit Hall

GLIMPSE360 is a Spitzer Space Telescope Exploration Science Project that is mapping the remaining 187 degrees of the Galactic Plane not previously observed with Spitzer. The survey covers longitude I=65-265 degrees (excluding I =102-109 and I=76-82). The latitude range is 2.6 degrees, slightly wider than the previous GLIMPSE surveys (2 degrees). The latitude center follows the

Galactic warp. Three visits on each sky position with 0.6 & 12s HDR frames makes this survey 13 times more sensitive than the previous GLIMPSE surveys of the inner Galactic plane. Even though we only have 2 IRAC bands in the post-cryogenic mission (3.6 and 4.5 microns) compared to GLIMPSE (3.6, 4.5, 5.8, 8.0, and 24 micron from the MIPSGAL), the combination of deeper exposures and lower confusion is allowing us to achieve all the science goals we had hoped for, including: mapping the edge of the stellar disk, and finding PAH bubbles from massive stars, outflows from intermediate to high-mass Young Stellar Objects (YSOs), low-to high-mass YSOs, stellar clusters, supernova remnants, infrared dark clouds (from extinction fitting of stars rather than silhouettes of PAH backgrounds), dusty evolved stars, and external galaxies in the Zone of Avoidance.

As of Oct. 1, 2010, about 80% of the data have been taken, and of that, about 70% have been processed at least once to produce source lists. We will present preliminary results and some wickedly pretty (green) pictures. Following the tradition of the previous GLIMPSE Legacy programs, we will deliver enhanced products to the community, consisting of high-quality point source lists and cleaned mosaic images. This research is supported by NASA/JPL.

241.17

RR Lyrae Survey of Tidally Distorted Globular Cluster Palomar 5 and its Surroundings

Lissa R. Miller¹, R. Zinn¹, A. Vivas², C. Baltay¹, N. Ellman¹, H. McCarrick³, M. Dogan¹, S. Duffau⁴ ¹Yale University, ²Centro de Estudios de Astronomia (CIDA), Venezuela, Bolivarian Republic of, ³Columbia University, ⁴University of Heidelberg, Germany.

Exhibit Hall

We present results from a survey of RR Lyrae variable stars (RRLs) in the vicinity of tidally distorted globular cluster Palomar 5. The survey area covers approximately 90 square degrees and includes the northern and southern tidal tails of Pal 5, as well as the surrounding area. Lightcurves have been obtained from the LaSilla-QUEST survey and we have used them to determine the distances to the stars. Additionally, spectra for a subset of the RRLs have been acquired. For those stars, we use the radial velocity measurements to establish membership in Pal 5, its tails, and other streams that fall within our survey area.

The Structure and Stellar Population of the Central 0.5 pc of the Milky Way Nuclear Star Cluster Tuan Do¹, A. Ghez², M. R. Morris², S. Yelda², J. R. Lu³, K. Matthews³, S. Wright⁴, J. Larkin² ¹UC, Irvine, ²UCLA, ³Caltech, ⁴UC, Berkeley.

Exhibit Hall

The core of the Galactic center nuclear star cluster contains populations of both old (> 1 Gyr) and young stars (~ 6 Myr). Recently, using laser guide star adaptive optics in conjunction with integral-field spectroscopy, it has been possible to distinguish between two populations to study their distribution and kinematics separately. The radial profile for the old stars was found to be significantly flatter than predicted by theories of stellar cusp formation around massive black holes. Based on number counts alone, it is unclear whether there is a 'hole' in the distribution of old stars at the center or if the space density of stars is constant. Distinguishing between these two scenarios will be important to constrain the range of models of cusp depletion. Here, we report on the results of a radial extension of our previous spectroscopic survey out to ~0.5 pc from Sgr A*, doubling the number of spectroscopically identified late-type giants. With the addition of astrometry, we are able to obtain 3D velocities for these stars, and in some cases, acceleration measurements. We are able to place better constraints on the three-dimensional profile of the cluster core than is possible with number counts alone. This survey also results in newly detected young, faint, B-stars along the plane of the young stellar disk at the Galactic center; significantly more stars were found than expected based on the previously observed luminosity function in this region. We also find that the radial profile of the surface density of young stars along the disk plane is flatter than was found in previous studies that sample largely perpendicularly to the disk plane.

241.19

Gamma-ray Constraints on Cosmic Rays in Galactic Winds

Kaiqi Hu¹, J. E. Everett¹, E. G. Zweibel¹

¹University of Wisconsin-Madison.

Exhibit Hall

Our group is constructing a hybrid thermal gas and cosmic-ray pressure driven wind model. This model is built on past work by Breitschwerdt et al. (1991) and Zirakashvili et al. (1996), and was motivated by unexplained high latitude Galactic X-ray emission observed by ROSAT, and further tested with radio synchrotron observations. In this poster, the role of cosmic-ray protons in generating gamma-ray emission in a Galactic wind is explored. In interacting with the wind plasma, cosmic-ray protons have three mechanisms to generate gamma-rays (pion production, Bremsstrahlung, and inverse Compton scattering), which can be detected by the Fermi Gamma-ray Space Telescope. To test the model, we have calculated the gamma-ray intensity from the wind model of Everett et al (2010), and we compare these predictions to the observed emission in the central Milky Way. Also, we have recently developed a new wind model which includes an azimuthal magnetic field and galactic rotation; we compare the driving in this improved model to the previous one, and report on the gamma-ray emissivity of this model as well. In the future we will apply this model to other galaxies which are observed to have a large scale wind, such as M82 and NGC 253. Understanding the high latitude gamma-ray emission from relativistic particles in galactic winds may help to constrain dark-matter models as well. This work has been supported by NASA through grant NNX10AO50G, and by the NSF through grants NSF AST-0907837 and NSF PHY-0821899 (to the Center for Magnetic Self-Organization in Laboratory and Astrophysical Plasmas).

242 *Stars, Cool Dwarfs, Brown Dwarfs* Poster Session *Exhibit Hall*

242.01

Abundances of Stars with Planets- Trends with Condensation Temperature

Simon C. Schuler¹, J. R. King², L. Ghezzi³, K. Cunha¹, V. V. Smith¹ ¹NOAO, ²Clemson University, ³Observatório Nacional, Brazil.

Exhibit Hall

We present the abundances of 18 elements for 10 stars with Jovian-mass planets based on highresolution, high-S/N spectroscopy obtained with the 9.2-m Hobby-Eberly Telescope (HET) and the 2.2-m MPG/ESO telescope at La Silla observatory. Stellar parameters have been derived spectroscopically and are in good agreement with previous determinations. The abundances are compared to condensation temperatures (T_{c}) of the elements, and the possible connection between T_{c} -dependent abundance trends and the presence of planets is discussed.

242.02

ACCOLADES: Astrometric Changes in Column Overlaps for Low-mass Archaic Dwarfs Espied in SDSS Andrew A. West¹, J. J. Bochanski², A. J. Burgasser³, J. K. Faherty⁴

¹Boston University, ²Penn State, ³U.C. San Diego, ⁴AMNH.

Exhibit Hall

We present preliminary results from ACCOLADES, a study of high proper motion, low-mass dwarfs, identified from two-epoch photometric observations in SDSS. The chip gap geometry in the SDSS photometric camera required that a small amount of each CCD column be imaged twice to ensure full spatial coverage in a given SDSS stripe. Occasionally, these overlapping regions were imaged months or years apart. Therefore, a subset of the SDSS catalog can be mined to produce accurate proper motions for stars that fall within these overlap regions. We selected a sample of late-M and L type dwarfs identified in these regions with time baselines longer than 1 year and conducted a spectroscopic follow-up campaign to compute 3D space motions. We present the spectroscopic analysis of our ACCOLADES sample and examine the utility of using this data mining method to identify low-mass components of the Galactic stellar halo.

242.03

Sizing Up the Stars

Tabetha S. Boyajian¹, K. von Braun², G. van Belle³, H. McAlister¹, M. López-Morales⁴, T. Henry¹, G. Schaefer¹, R. White¹, S. T. Ridgway⁵, D. Ciardi², T. ten Brummelaar¹, L. Sturmann¹, J. Sturmann¹, N. Turner¹, C. Farrington¹, P. Goldfinger¹

¹Georgia State University / CHARA, ²NexScI/Caltech, ³ESO, Germany, ⁴Carnegie / DTM, ⁵NOAO. Exhibit Hall

This work focuses on determining the fundamental properties of nearby, main sequence, A, F, G, K, and M-type stars. We present the results of angular diameters (average error ~1.5%) obtained via interferometric observations made with the CHARA Array. These measurements combined with HIPPARCOS and ground-based parallaxes and bolometric fluxes provide an empirical determination of their effective temperatures, linear radii, and absolute luminosities. We derive empirically based relations for the stellar effective temperature for these types of stars, which are accurate to the 1% level.

Additionally, the masses and ages of the A, F, and G stars are determined by fitting the CHARAdetermined temperatures, radii, and luminosities to Yonsei-Yale model isochrones, and we compare these results to those obtained by indirect methods. We show that for most cases the theoretical stellar radii for stars >1.3 Msun and <0.65 Msun are too small compared to observed radii by 5% and 15%, respectively (and temperatures too hot by 2% and 7%, respectively). For the early-type stars, these overestimated temperatures and underestimated radii appear to cause an additional offset in the star's surface gravity measurements, which consequently yield higher masses and younger ages. Furthermore, we elaborate on these discrepancies seen for the late-type stars where the onset of convection plays a significant role in determining the model radii for these stars.

242.04

Discerning Spectral Features in L Dwarfs

Alejandro Nunez¹, K. Cruz², A. J. Burgasser³, J. D. Kirkpatrick⁴, I. N. Reid⁵ ¹CUNY Hunter College, ²CUNY Hunter College & AMNH, ³University of California at San Diego, ⁴Caltech/IPAC, ⁵STScI.

Exhibit Hall

Brown dwarfs are star-like objects that, due to their very low masses (less than 75 Jupiter masses,) never reach the main sequence, and instead cool with time. This cooling leads to a breakdown of the relationship between temperature and mass that exists for stars. Therefore, brown dwarfs with similar temperatures (as indicated by spectral type) could have very different masses and ages. We are investigating the near-infrared spectra of L dwarfs with the same optically derived spectral types (implying similar effective temperatures) with the goal of distinguishing subtle differences, patterns, and/or correlations among absorption features that could reveal information about their ages and masses. Our sample consists of 43 LO-L8 dwarfs with both optical and near-infrared spectra, thus covering the 0.65 to 2.4-micron range. Our analysis included objects with either "typical" or peculiar spectra. Some of the objects with peculiar spectra are suspected low-gravity/young and blue/lowmetallicity dwarfs. For each optical type, we normalized and overplotted the spectra in four bands separately: Optical, J, H, and K band. Each resulting plot was examined by eye to look for subtle differences in spectral absorption features, likely due to age and mass. We present the preliminary results from this detailed spectral analysis. In particular, our analysis reveals the major spectral differences in the near infrared of both "red" and "blue" L dwarfs. This work was funded by the RISE Grant GM R25 6066, and we acknowledge the hospitality of the American Museum of Natural History.

242.05

RECONS Reaches to 25 Parsecs

Todd J. Henry¹, M. R. Boyd², S. B. Dieterich³, C. T. Finch⁴, P. A. Ianna⁵, W. Jao³, A. R. Riedel³, J. P. Subsavage⁶, A. M. Tanner³, J. G. Winters³

¹RECONS, ²RECONS / GaTech, ³RECONS / GSU, ⁴RECONS / USNO, ⁵RECONS / U. Virginia, ⁶RECONS /CTIO. Exhibit Hall

RECONS (Research Consortium on Nearby Stars, www.recons.org) is expanding its careful reconnaissance of the solar neighborhood from the original 10 parsec core sample to 25 parsecs. The resulting RECONS Database will expand the number of stellar systems for which we have detailed observations (astrometry, photometry, spectroscopy) and derived information (metallicity, multiplicity, exoplanets) from about 250 systems to 4000-6000 systems.

Here we outline the new-and-improved 25 parsec sample, significantly updated from the NStars effort of a decade ago. To date, only 2000 systems have trigonometric parallaxes placing them within 25 parsecs, with more than 10% contributed by the RECONS effort at CTIO. In fact, an accurate estimate of the expected population is elusive, as new systems are being found as close as 4 parsecs, making extrapolations to 25 parsecs highly uncertain. We look forward to upcoming contributions made to the census by RECONS, SkyMapper, Pan-STARRS, LSST, and Gaia, and discuss how each of these efforts will play a role. During the next decade, census work is important because of surging interest in the nearest stars --- our stellar neighbors will offer the best answers to such fundamental questions as "What types of stars really populate the Galaxy?", "How many planets orbit nearby stars?", and "Is there life on any of those planets?"

This work is currently supported by the NSF under AST 09-08402.

242.06

Stellar Diameters and Limb-Darkening with Extreme Precision: Coherent Integration with the Navy Prototype Optical Interferometer

Anders M. Jorgensen¹, T. Hall¹, D. Paiton¹, H. R. Schmitt², J. T. Armstrong², D. Mozurkewich³, E. K. Baines², R. B. Hindsley², D. Hutter⁴, S. R. Restaino², B. Curtis¹, M. Brown¹

¹New Mexico Tech, ²Naval Research Laboratory, ³Seabrook Engineering, ⁴Naval Observatory, Flagstaff Station.

Exhibit Hall

We will present three stellar diameters measurements in which we use coherent integration of data from the Navy Prototype Optical Interferometer. Coherent integration is a post-processing technique which corrects for atmospheric optical-path-difference shifts in interferometric data and allows, effectively, to increase the integration time of optical interferometric data indefinitely by summing many short exposures suitably shifted. This is significant because coherent integration, which allows the complex visibilities to be summed in phase, greatly improves the signal-to-noise ratio over traditional techniques which average squared visibilities. The improvement is particularly dramatic for faint targets, and/or when the visibility amplitude is very small. This is important when measuring stellar diameters on resolving baselines that include visibility nulls. Those baselines best constrain the diameters. However in order to take full advantage of the null as a diameter measure it is necessary to obtain high-SNR measurements around the null, which is possible with coherent integration. We will present observations of three stars for which coherent integration has been used to measure the visibility near the null very precisely. We will then fit these visibilities to uniform disk and limb-darkened visibility models to obtain extremely high precision diameters (1:500 to 1:1000) and limb-darkening parameters.

242.07

Measuring the Masses of the Most Massive Stars

Philip Massey¹, K. Neugent¹, N. Morrell², L. Penny³, D. R. Gies⁴, K. Eastwood⁵ ¹Lowell Obs., ²Las Campanas Observatory, Chile, ³College of Charleston, ⁴Georgia State Univ., ⁵Northern

Arizona University.

Exhibit Hall

The relationship between mass and luminosity is poorly determined for high mass stars, with stellar atmosphere analysis often yielding lower estimates of the masses than stellar evolutionary models predict. For the hottest massive stars in the Magellanic Clouds such differences can be as much as a factor of two. This "mass discrepancy" problem has been known for 15 years. During this time the physics of both the stellar atmosphere and stellar evolutionary models has improved considerably, but the problem still remains with us. We've concluded that resolving this discrepancy requires an observational approach.

We have been determining the masses of the highest mass stars *directly* from Kepler's 3rd law using massive eclipsing binaries, and comparing these to what is predicted by stellar evolutionary tracks. To identify the sample, we have used four years of intensive queue observations on the SMARTS Yale and LCO Swope 1.0-m telescope. This photometry has allowed us to pick out appropriate systems, whose light-curves and periods indicate a good chance that the components are not interacting, and that the results will be representative of single stars. Follow-up spectroscopy has been carried out on the

Magellan 6.5-m Baade and Clay telescopes using IMACS and MagE, respectively. We present our preliminary results here.

This work has been funded in part through the National Science Foundation (AST-0506577) and NASA (HST GO-10612).

242.08

The Young Solar Analogs Project

Christopher J. Corbally¹, R. O. Gray², J. M. Saken²

¹Vatican Observatory, ²Appalachian State Univ..

Exhibit Hall

Since 2007 we have been monitoring the Ca II K chromospheric emission of a set of 23 young solar analogs (YSA). These stars, carefully selected from the Nearby Stars database (Gray et al. 2003, 2006), have spectral types between F8 and K2, and ages between 300 Myr and 1.5 Gyr. The goal of this project is to learn more about the sun-earth environment at a time, about 3.8 billion years ago, when life was gaining a foothold on the young earth. Of particular interest are the characterization of long-term stellar activity cycles, the determination of rotational periods, and the detection of short-term phenomena such as stellar flares. Spectroscopic observations began in 2007, and just recently we have added a simultaneous multi-band photometric component to the project.

We will present preliminary results from the project, and discuss future developments to the program.

242.09

Searching for Wide Low-Mass Tertiary Companions to Binary Star Systems

Stephanie Douglas¹, P. Allen¹

¹Frankin & Marshall College.

Exhibit Hall

We will present the results from common proper motion searches for wide low-mass stellar and substellar companions to known tight binary systems. Observations were made with the 4m telescope at KPNO and the 31" NURO telescope at Lowell Observatory. The binary systems observed at KPNO are spectroscopic binaries, while the systems targeted at NURO are unresolved or partially resolved white dwarf-M dwarf binaries. We are testing recent simulations of star formation that predict that tight binary systems form by transferring angular momentum to a lower mass third companion. Any genuine companions will be able to serve as 'benchmark' low-mass stars and brown dwarfs. The central binary, particularly the white dwarfs, will allow us to estimate independent values of age and metallicity for the wide, low-mass companion. The candidates are primarily selected using astrometry, and then the list is refined with photometry. We present the candidate companions we have found to date and the future plans for this project.

242.10

A Photometric Survey of Ori OB1b

Allison T. Merritt¹, W. Sherry²

¹University of California, Berkeley, ²University of Arizona. Exhibit Hall

Several mechanisms have been suggested to describe the formation of sub-stellar mass objects (SSMOs), specifically brown dwarfs. Each proposed mechanism predicts a unique spatial distribution of the brown dwarfs relative to the O and B stars of the association. We have 9 square degrees of optical (VRI) data and 7 square degrees of NIR (JHK) data of Orion OB1b. The purpose of the survey is to obtain the photometric data that will allow us to determine the spatial distribution of brown dwarfs in this region and constrain the various formation theories. We present an overview of the survey, with an emphasis on the NIR data, as well as color-magnitude diagrams. This research was supported by the

NOAO/KPNO Research Experiences for Undergraduates (REU) Program which is funded by the National Science Foundation Research Experiences for Undergraduates Program and the Department of Defense ASSURE program through Scientific Program Order No. 13 (AST-0754223) of the Cooperative Agreement No. AST-0132798 between the Association of Universities for Research in Astronomy (AURA) and the NSF.

242.11

Spectroscopic Classification of 3,717 Nearby M Stars

Naomi Alpert¹, S. Lepine²

¹Vassar College, ²American Museum of Natural History. Exhibit Hall

Collected spectra of nearby stars are used to identify and classify M-Dwarfs according to temperature and metallicity. The stars examined are all located within approximately 50 parsecs of our Sun and were selected from the LSPM-north proper motion catalog. The spectra were collected over dozens of observing runs from telescopes at MDM, Lick and KPNO. We find the spectral classification to be sensitive to radial velocity shifts and variations in instrument sensitivity so in order to obtain a uniform classification, we must correct the spectra to account for these potential effects. In some cases, these effects were great enough that the original classification needed to be adjusted. A final classification was obtained for 3717 M-Dwarfs and 245 K-Dwarfs. The final distribution of these classifications shows objects with subtypes M3 and M4 to be the most common in our sample (over 1,800 spectra). Within the sample of spectra, 9% were classified as metal-poor subdwarfs (181 stars), extreme subdwarfs (100 stars), or ultrasubdwarfs (64 stars).

242.12

The Chemical Abundances of Stars in the Halo (CASH) Project. II. New Extremely Metal-poor Stars Julie A. Krugler¹, A. Frebel², I. U. Roederer³, C. Sneden¹, M. Shetrone¹, T. Beers⁴, N. Christlieb⁵ ¹University of Texas, ²Harvard-Smithsonian Center for Astrophysics, ³Carnegie Observatories, ⁴Michigan State University, ⁵University of Heidelberg, Germany. Exhibit Hall

We present new abundance results from the Chemical Abundances of Stars in the Halo (CASH) project. The ~500 CASH spectra were observed using the Hobby-Eberly Telescope in "snapshot" mode and are analyzed using an automated stellar parameter and abundance pipeline called CASHCODE. For the 20 most metal-poor stars of the CASH sample we have obtained high resolution spectra using the Magellan Telescope in order to test the uncertainties and systematic errors associated with the snapshot quality (i.e., R~15,000 and S/N~65) HET spectra and to calibrate the newly developed CASHCODE by making a detailed comparison between the stellar parameters and abundances determined from the high resolution and snapshot spectra. We find that the CASHCODE stellar parameters (effective temperature, surface gravity, metallicity, and microturbulence) agree well with the results of the manual analysis of the high resolution spectra. We present the abundances of three newly discovered stars with [Fe/H] < -3.5. For the entire pilot sample, we find typical halo abundance ratios with alpha-enhancement and Fepeak depletion and a range of n-capture elements. The full CASH sample will be used to derive statistically robust abundance trends and frequencies (e.g. carbon and n-capture), as well as placing constraints on nucleosynthetic processes that occurred in the early universe.

Extending M Dwarf Variability Studies to Longer Wavelengths

James R. A. Davenport¹, A. Becker¹, A. F. Kowalski¹, E. J. Hilton¹, S. L. Hawley¹

¹University of Washington.

Exhibit Hall

Flares on M dwarfs occur stochastically, and the statistical frequency of such events is well characterized in the optical. Flares and stellar variability are a source of confusion for large time-domain surveys, and a unified physical model of these magnetically driven events across all spectral types still awaits discovery. To correctly predict the occurrence rate of M dwarf variability in future astronomical surveys, we must understand the full SED of these events as completely as possible. We have constructed a sample of ~4000 M dwarfs with a broad range of properties, each with thousands of epochs of observation. This matched data set comes from the SDSS Stripe 82 and LINEAR databases in the optical, and 2MASS Calibration Scan database in the NIR. We present preliminary results that extend the flaring rate and variability signature to longer wavelengths, where many future scientific missions such as LSST, JWST, and others will operate.

242.14

The CNO Bi-cycle in the Open Cluster NGC 752

Keith Hawkins¹, S. Schuler², J. King³, L. The³ ¹Ohio University, ²NOAO, ³Clemson University. Exhibit Hall

The CNO bi-cycle is the primary energy source for main sequence stars more massive than the sun. To test our understanding of stellar evolution models using the CNO bi-cycle, we have undertaken lightelement (CNO) abundance analysis of three main sequence dwarf stars and three red giant stars in the open cluster NGC 752 utilizing high resolution ($R \simeq 50,000$) spectroscopy from the Keck Observatory. Preliminary results indicate, as expected, there is a depletion of carbon in the giants relative to the dwarfs. Additional analysis is needed to determine if the amount of depletion is in line with model predictions, as seen in the Hyades open cluster. Oxygen abundances are derived from the highexcitation O I triplet, and there is a 0.19 dex offset in the [O/H] abundances between the giants and dwarfs which may be explained by non-local thermodynamic equilibrium (NLTE), although further analysis is needed to verify this. The standard procedure for spectroscopically determining stellar parameters used here allows for a measurement of the cluster metallicity, $[Fe/H] = 0.04 \pm 0.02$. In addition to the Fe abundances we have determined Na, Mg, and Al abundances to determine the status of other nucleosynthesis processes. The Na, Mg and Al abundances of the giants are enhanced relative to the dwarfs, which is consistent with similar findings in giants of other open clusters. Support for K. Hawkins was provided by the NOAO/KPNO Research Experiences for Undergraduates (REU) Program which is funded by the National Science Foundation Research Experiences for Undergraduates Program and the Department of Defense ASSURE program through Scientific Program Order No. 13 (AST-0754223) of the Cooperative Agreement No. AST-0132798 between the Association of Universities for Research in Astronomy (AURA) and the NSF.

242.16

Nearby Motionless Stars

Adric R. Riedel¹, T. J. Henry¹, R. J. White², I. Song³, E. N. Jensen⁴, RECONS ¹Georgia State Univ./RECONS, ²Georgia State Univ., ³University of Georgia, ⁴Swarthmore College. Exhibit Hall

Almost 15% of all systems within 25 parsecs should be moving slower than 0.18 arcseconds per year, but traditional proper motion searches for nearby systems will miss them. Apart from USNO-B1, work by

Lepine and Deacon, and stars bright enough to be seen by Hipparcos, the proper motion regime is almost completely unexplored.

We have made a photometric search of the SuperCOSMOS database (Hambly 2002) to locate new nearby systems. The most promising targets moving slower than 0.18"/yr are being followed up with low resolution spectroscopy, CCD photometry, and trigonometric parallaxes from the CTIOPI program. Our first results have revealed nearby nearly-motionless systems like SCR2049-4012 (9.2 pc, 0.06"/yr), and a large number of apparent binary and young systems (a few perhaps as young as TW Hydra) of great astrophysical interest.

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242.17

Youth Indicators of Late-M Dwarfs

Daniel Feldman¹, K. Cruz², S. Lépine³, N. Alpert⁴

¹CUNY College of Staten Island, ²CUNY Hunter College & AMNH, ³AMNH, ⁴Vassar College. Exhibit Hall

We present a study in which we searched for a correlation between weak Na absorption doublet (8183Å, 8194Å) and strong H-Alpha emission (6563Å) in late-M dwarf stars (M6-M9), as both are indicative of youth. Our sample consists of late-M Dwarfs from the LSPM Survey (Lépine and Shara, 2005), which contain stars with measured proper motions of mu > 40 mas/yr. Measurements for emission and absorption strength were made using spectral indices. Our preliminary results are presented; future work will include a similar analysis of early type M Dwarfs, as well as kinematics. This work was funded by the CUNY Summer Undergraduate Research Program, as well as the CUNY Macaulay Honors College, and we acknowledge the hospitality of the American Museum of Natural History.

242.18

X-ray and Radio Observations of LP349-25

Sarah J. Schmidt¹, R. A. Osten², S. L. Hawley¹, P. Ngoc³, N. Reid²

¹University of Washington, ²Space Telescope Science Institute, ³Academia Sinica Institute for Astronomy & Astrophysics, Taiwan.

Exhibit Hall

For a long time ultracool dwarfs (stellar objects with spectral types later than M7) were not thought to display any of the characteristics associated with the presence and action of strong magnetic fields, but surprisingly, recent observations have demonstrated the continuation of chromospheric and coronal indicators into this regime. The radio and X-ray behavior of ultracool dwarfs in particular show strikingly different behaviors when compared to what is seen in higher mass stars: objects detected at X-ray wavelengths show the decline of plasma heating with effective temperature but with examples of flarelike behavior which suggest some continuation in behavior from early-mid M dwarf stars. Radio detections of ultracool dwarfs are characterized by variability which occurs on timescales associated with the rotation period, and the dominant emission mechanism may switch from the incoherent gyrosynchrotron seen on earlier M stars to a coherent maser process. There is a discontinuity between radio-detected ultracool dwarfs (which tend to be X-ray weak or undetected) and X-ray detected ultracool dwarfs, which tend to be radio weak or undetected. The young brown dwarf binary LP 349-25 is a peculiar radio emitter due to its lack of radio variability on both long and short timescales. The lack of rotational modulation presents difficulties for the generation of radio emission in strong large scale magnetic fields. To further investigate the conditions of LP349-25, we present simultaneous radio and xray observations of LP349-25. Initial analysis of the data shows that the radio emission continues to be constant and that LP349-25 additionally shows quiescent x-ray emission. This allows us to place

additional constraints on the mechanism for radio emission in LP349-25 and explore the conditions which cause disparate high energy behaviors in ultracool dwarfs.

242.19

NEMESIS: Near Encounters with M-dwarfs from an Enormous Sample and Integrated Simulations John J. Bochanski¹, R. E. Sanderson², A. A. West³, A. J. Burgasser⁴

¹Penn State, ²Massachusetts Institute of Technology, ³Boston University, ⁴UC, San Diego. Exhibit Hall

The latest spectroscopic catalog of M dwarfs identified in the Sloan Digital Sky Survey provides radial velocities, proper motions and distances for nearly 40,000 low-mass stars. Using the full 6D phase space coverage and a realistic Galactic potential, we calculated orbits for each star in the sample. The sample consists of stars from both the thin and thick disks, and the orbital properties between the two groups are compared. We also examine trends in orbital properties with spectroscopic features, such as Balmer emission and molecular bands, that should correlate with age.

In addition, we have identified a number of stars that will pass very close to the Sun within the next 1000 Myrs. These stars form the "Nemesis" family of orbits. Potential encounters with these stars could have a significant impact on orbits of Oort Cloud and Kuiper Belt members as well as the planets. We comment on the probability of a catastrophic encounter within the next 1000 Myrs.

242.20

M Dwarf Atomic and Molecular Features in SDSS DR7 Spectra

Meghin Spencer¹, J. R. A. Davenport¹, A. A. West², S. L. Hawley¹

¹University of Washington, ²Boston University.

Exhibit Hall

Large, homogenous spectroscopic datasets offer the opportunity to investigate the behavior of stellar atmospheres as a function of various stellar parameters with unprecedented statistical accuracy. We use the SDSS DR7 spectroscopic catalog of 70,000 low mass stars to investigate the changes in atomic and molecular features that occur with differing mass, temperature, metallicity, and level of magnetic activity.

242.21

The Differential Rotation of Very Low-Mass Stars Matthew K. Browning¹

¹Canadian Institute for Theoretical Astrophysics, Canada.

Exhibit Hall

We present 3-D MHD simulations of fully convective stars rotating at various rates. We report here in particular on the zonal flows (differential rotation) realized in these simulations, and on how magnetic fields generated by dynamo action act to partly quench those flows. In general, the simulations establish surface differential rotation profiles that are solar-like (with a fast equator and slow poles) whenever rotation is sufficiently strong; when the simulated stars rotate very slowly, however, the differential rotation is typically anti-solar (with a retrograde equator). This change in behavior may be observable through photometric monitoring with, e.g., Kepler. We analyze the maintenance of these flows and compare the angular momentum transport realized here with that in more massive stars, giant planets, and accretion disks.

242.22

Magnetic Cycles in a Wreath-Building Dynamo Simulation of a Young Solar-type Star Benjamin Brown¹, M. S. Miesch², M. K. Browning³, A. S. Brun⁴, N. J. Nelson⁵, J. Toomre⁵ ¹Univ. of Wisconsin - Madison, ²High Altitude Observatory, ³Canadian Institute for Theoretical Astrophysics, Canada, ⁴DSM/IRFU/SAp, CEA-Saclay and UMR AIM, CEA-CNRS-Université Paris, France, ⁵JILA and Dept. Astrophysics & Planetary Sciences, Univ. of Colorado at Boulder. Exhibit Hall

Stars like the Sun build global-scale magnetic fields though dynamo processes in their convection zones. There, global-scale plasma motions couple with rotation and likely drive cycles of magnetic activity, though the exact processes at work in solar and stellar dynamos remain elusive. Observations of younger suns indicate that they rotate quite rapidly, have strong magnetic fields at their surfaces, and show signs of cyclic activity. Here we explore recent 3-D MHD simulations of younger, more rapidly rotating solar-type stars conducted with the anelastic spherical harmonic (ASH) code. These simulations of global-scale convection and dynamo action produce strikingly organized magnetic structures in the bulk of their convection zones. Wreaths of magnetic field fill the convection zone and can undergo regular cycles of polarity reversal. Indeed, we find that cyclic behavior is a common feature throughout the parameter space we have explored. Though these magnetic wreaths can coexist with tachoclines of penetration and shear, they do not rely on that internal boundary layer for their formation or persistence. Tachoclines may play a less critical role in the stellar dynamos of younger Suns than has been supposed in solar dynamo theory.

242.23

Distances to Eclipsing M-Dwarf Binary Systems

Gail Schaefer¹, G. T. van Belle², K. von Braun³, T. S. Boyajian¹, D. R. Ciardi³, M. Lopez-Morales⁴ ¹Georgia State University, ²European Southern Observatory, Germany, ³Caltech, ⁴Institut de Ciencies de L'Espai, Spain.

Exhibit Hall

We present preliminary trigonometric parallax measurements of five nearby M-dwarf eclipsing binary systems obtained using the Fine Guidance Sensors (FGS) on board the Hubble Space Telescope. We also obtained photometric and spectroscopic observations to classify the background astrometric reference stars in order to convert the parallaxes from relative to absolute. Based on the distance measurements, we can calculate model-independent luminosities for these M-dwarf binaries. Combined with their dynamical masses, these measurements provide anchor points for the low-mass end of the mass-luminosity diagram.

242.24

Making The Most Of Flaring M Dwarfs

Nicholas Hunt-Walker¹, E. Hilton¹, A. Kowalski¹, S. Hawley¹, J. Matthews², J. Holtzman³ ¹University of Washington, ²University of British Columbia, Canada, ³New Mexico State University. Exhibit Hall

We present observations of flare activity using the Microvariability and Oscillations of Stars (MOST) satellite in conjunction with simultaneous spectroscopic and photometric observations from the ARC 3.5-meter, NMSU 1.0-meter, and ARCSAT 0.5-meter telescopes at the Apache Point Observatory. The MOST observations enable unprecedented completeness with regard to observing frequent, low-energy flares on the well-known dMe flare star AD Leo with broadband photometry. The observations span approximately one week with a 60-second cadence and are sensitive to flares as small as 0.01-magnitudes. The time-resolved, ground-based spectroscopy gives measurements of H α and other important chromospheric emission lines, whereas the Johnson U-, SDSS u-, and SDSS g-band photometry provide color information during the flare events and allow us to relate the MOST observations to decades of previous broadband observations. Understanding the rates and energetics of flare events on M dwarfs will help characterize this source of variability in large time-domain surveys such as LSST and
Pan-STARRS. Flare rates are also of interest to astrobiology, since flares affect the habitability of exoplanets orbiting M dwarfs.

242.25

HST/FGS Parallaxes of Metal-Poor Main Sequence Stars: An Update

Brian C. Chaboyer¹, G. F. Benedict², B. E. McArthur², A. McWilliam³, E. Nelan⁴, R. J. Patterson⁵, A. Sarajedini⁶, G. Feiden¹

¹Dartmouth College, ²University of Texas at Austin, ³Observatories of the Carnegie Institution of Washington, ⁴Space Telescope Science Institute, ⁵The University of Virginia, ⁶University of Florida. Exhibit Hall

We are using the Fine Guidance Sensors (FGS) on HST to obtain parallaxes of 9 metal-poor ([Fe/H] < -1.5) main sequence stars. The HST parallaxes are expected to have an accuracy of 0.2 mas (millisecond of arc), leading to absolute magnitude uncertainties of

+/-0.05 mag for a given star. These stars will be used to test metal-poor stellar evolution models and to determine main sequence fitting distances to a large number of low metallicity globular clusters. FGS data has been obtained successfully for all stars during cycle 17 and will be complete at the end of cycle 18. ACS observations with the the F606W and F814W filters have been obtained for each star. ACS and ground based photometry is presented for the 9 stars. We are currently obtaining ground based high resolution spectra of all target stars which will be used to determine the composition of each star. A new grid of stellar evolution models and isochrones, which incorporate a range of different assumptions regarding the physics of stellar evolution, are currently being computed.

242.26

Finding Friends for Red Dwarfs

Jennifer G. Winters¹, T. J. Henry¹, M. R. Boyd², N. C. Hambly³, RECONS

¹Georgia State University, ²Georgia Institute of Technology, ³Royal Observatory, University of Edinburgh, United Kingdom.

Exhibit Hall

Stellar multiplicity provides fundamental clues about the nature of star formation, the distribution of baryonic mass in the Universe, and the evolution of stellar systems over time. How stars are parceled into singles, doubles, and higher order multiples also provides clues about the angular momentum distribution in stellar systems and constraints on whether planets may be found. Because of their large numbers, arguably the best sample that can be studied to understand stellar multiplicity are the nearby M-dwarfs.

Companion searches have been done for M-dwarfs during the past few decades, but all of the surveys have had on the order of 100 targets. With samples of this size, our statistical understanding of the distribution of companions is quite weak. We are currently systematically surveying ~1200 red dwarfs that have trigonometric parallaxes placing them within 25 pc of the Sun for stellar companions at separations of 1" to 10'. By obtaining I-band images using the CTIO 0.9m in the south and the Lowell 42in in the north, we are probing the environs of these systems for companions at separations of 1" to 3'. Because the systems all have accurate parallaxes, biases inherent to photometrically-selected samples are eliminated. A complementary reconnaissance of wider companions out to 10' is also being done via blinking of SuperCOSMOS BRI images.

The results will allow statistical analyses of the nearby M-dwarf population, refinement of the solar neighborhood membership roster, and improvement of the mass function for these objects at the end of the main sequence. This is the largest, most comprehensive study ever done of the multiplicity of the most common stars in the Galaxy, one that will hopefully reveal those hidden friends lurking in the darkness.

This work is supported by NSF grant AST 09-08402, the SMARTS Consortium, and Georgia State University.

242.27

Calculating Luminosities for a Large Sample of Brown Dwarfs

Frank Stabile¹, K. Allers²

¹Fordham University, ²Bucknell University. Exhibit Hall

We set out to expand the number of brown dwarfs with calculated luminosities and bolometric corrections. We chose our sample by collecting published near infrared spectra of brown dwarfs from the Spex Prism Library. The sample is predominantly L and T type dwarfs, although some M dwarfs have been included. These spectral energy distributions were extended to optical wavelengths using SDSS photometry or published optical spectra. Similarly, the spectra were extended out to longer wavelengths using Spitzer photometry and published spectra. The spectrum for each object covers a range from roughly 0.6 microns to 15 microns. In the cases where the photometry was not available, we developed a robust method to approximate missing data utilizing both the published spectral types of the objects as well as their NIR colors. Our initial results with an expanded sample fit well with previously published work.

242.28

Ultraviolet Spectral Synthesis of HgMn Stars

Ronald-Louis Ballouz¹, E. L. Fitzpatrick¹

¹Villanova University.

Exhibit Hall

We present a detailed analysis of the ultraviolet spectrum of HgMn stars. Using the SPECTRUM code of Gray and Corbally (1994) we perform a high resolution, order by order, analysis of archival spectroscopic data from the International Ultraviolet Explorer (IUE). The data set used here consists of IUE spectrophotmetry obtained using the high-resolution echelle observing mode with both the short-wavelength (1150-2000 Angstroms) and the long-wavelength (1900-3200 Angstroms) cameras. This study builds upon detailed spectral synthesis work of the AOV star Vega by Fitzpatrick (2010) and the analysis of HgMn star IUE spectra by Smith (1993) . Through a chi² minimization routine the analysis yields detailed abundances, effective temperatures, radial velocities, surface gravities, and microturbulence velocities. Thusly, we improve on the parameter determinations for HgMn and comment on the abundance patterns of these chemically peculiar B-stars.

This work is supported by the Villanova University Research for Undergraduates Awards Program and NASA programs.

242.29

Brown Dwarfs from SDSS-III Marvels: A Look At The Population Of The Desert

Nathan M. De Lee¹, J. Ge¹, S. Gaudi², B. Lee¹, S. Fleming¹, B. Ma¹, K. Stassun³, J. Pepper³, D. Nguyen¹, L. Hebb³, J. Wisniewski⁴, S. Mahadevan⁵, C. Reyle⁶

¹Univ. of Florida, ²Ohio State University, ³Vanderbilt University, ⁴Univ. of Washington, ⁵Penn State University, ⁶Besançon Observatory, France.

Exhibit Hall

The SDSS-III MARVELS survey is a comprehensive radial velocity survey of 10,000 nearby F through K stars, between magnitudes 7.6 < V < 12.0. The primary goal of this survey is to search for planets among a homogeneous set of stars, which will be used to put constraints on formation and evolution models. This survey is also very sensitive to more massive companions such as brown dwarfs (BDs) and low mass binaries. We will discuss an ongoing project aimed at characterizing the properties of these

massive companions. As part of the first two years of the six year MARVELS project, approximately 2,000 stars were searched for BDs from 1 to 180 days using a modified Lomb-Scargle periodogram, yielding roughly a dozen candidates. The completeness of this BD dataset will be determined from Monte Carlo simulations, and the completeness corrected dataset will be used to compute the fraction of solar-like stars that host short- to intermediate-period BD companions. Several of these BD have host stars characterized allowing us to explore in detail their place in the BD desert and how parameters like spectral type and metallicity play a role. Finally, this large homegeneous radial velocity survey will be placed in the larger context of our current knowledge about BD statistics.

244

Cosmic Microwave Background Poster Session *Exhibit Hall*

244.01

Stacking Catalog Sources in WMAP Data

Kasey Schultz¹, K. M. Huffenberger¹ ¹University of Miami.

Exhibit Hall

Following Sawangwit & Shanks (2010), we stack WMAP 7-year data around extragalactic point sources to probe deviations in the source profiles from the Jupiter-modeled WMAP beams. Like them, we find that the stacked source profiles are broader than the WMAP model beam. Subtracting a foreground model changes the stacked profiles significantly, particularly at Q-band, but even after subtraction, the profiles appear significantly wider than the WMAP models in the Q-, V-, and W-bands, and have much heavier tails.

While ground-based CMB measurements and cross-correlations with WMAP data mean that serious problems with the WMAP beam models are unlikely, the too-broad source profiles still require explanation. We explore several possibilities with parametric fits to the stacked profiles, probing the source frequency spectrum and positional uncertainty. These explanations appear to be unlikely candidates. Finally, we explore the selection bias at the faint end of the WMAP catalog, where sources lying along the same line of sight as a positive CMB fluctuation may be boosted above the WMAP catalog threshold.

244.02

Measurement Of The Null In The Sunyaev-zel'dovich Effect With Z-spec

Michael B. Zemcov¹, J. Aguirre², J. Bock³, M. Bradford³, J. Glenn⁴, R. Lupu², H. Nguyen³ ¹California Insitute of Technology, ²University of Pennsylvania, ³Jet Propulsion Laboratory, ⁴University of Colorado, Boulder.

Exhibit Hall

The (thermal) Sunyaev-Zel'dovich (SZ) effect is a decrement in the brightness of the cosmic microwave background (CMB) as seen through galaxy clusters at mm wavelengths and an increment at sub-mm wavelengths which passes though a null at 217 GHz when the scatttering plasma is cold. To correctly describe the SZ distortion when relativisitic electrons are present or the cluster is moving with respect to the CMB requires the addition of correction terms usually called the `non-thermal' and `kinetic' SZ effects. These corrections change both the shape and null frequency of the SZ spectral distortion and should be detectable using suitable instruments. We have measured the SZ effect in the bright galaxy cluster RXJ 1347-1145 using Z-Spec, a spectro-photometer which has uniquely high spectral resolution and continuous coverage between 180 and 300 GHz. This paper presents preliminary results of this

measurement, cluster parameters derived from it, and the outlook for future measurements of the SZ effect using mm-wave spectro-photometers.

244.03

Expected Circular Polarization Detection by the Primordial Inflation Polarization Explorer (PIPER) Wenli Mo¹, A. Kogut²

¹Johns Hopkins University, ²Goddard Space Flight Center. Exhibit Hall

The Primordial Inflation Polarization Explorer (PIPER) is a balloon-borne mission searching for the polarization of the cosmic microwave background (CMB) created during the inflationary epoch of the early universe. Instruments will detect both linear and circular polarization (CP) with high precision. Though CP is not predicted in the CMB, it does exist in extragalactic radio sources. The objective of this study is to determine PIPER's expected CP detection from extragalactic radio sources. We will discuss the collection of CP detection from fifty-eight different sources and the expected flux when scaled using the PIPER beam and observing frequency. Also, we will present a CP sky map, which provides a sample of the intensity and location of these sources.

245

Starburst Galaxies Poster Session *Exhibit Hall*

245.01

The Extended Hot Halo of NGC3079

Ralf-Juergen Dettmar¹, M. Wezgowiec¹, D. J. Bomans¹

¹Ruhr-University, Germany.

Exhibit Hall

NGC3079 is a nearby edge-on galaxy harboring a composite starburst-AGN nucleus and a disk with a high starformation rate. Earlier observations showed an expanding bubble in the nucleus and some hot gas above the disk. Using XMM-NEWTON data we now trace the hot halo of NGC 3079 to much larger distances and show that the global structure is X-shaped, a configuration similar to the one observed for cosmic ray halos of several galaxies in the radio-continuum (e.g. in NGC 5775). This large scale distribution of the X-ray halo is discussed in comparison to radio-continuum and H_{alpha} data. The X-ray observations have sufficient statistics to allow for spectral analysis at different radial distances from the disk and to search for temperature differences. We also investigate the interaction of the hot halo gas with companion galaxies.

This work is supported by DLR Verbundforschung "Extraterrestrik".

245.02

Diffuse Far-UV Line Emission from Circumgalactic Gas

Nicholas Nell¹, K. France¹, J. C. Green¹, C. Leitherer²

¹CASA, ²Space Telescope Science Institute.

Exhibit Hall

We present new ultraviolet (UV) observations of the luminous compact blue galaxy KISSR242, obtained with the Hubble Space Telescope-Cosmic Origins Spectrograph (HST-COS). We identify multiple resolved sub-arcsecond near-UV sources within the COS aperture. The far-UV spectroscopic data show strong outflow absorption lines, consistent with feedback processes related to an episode of massive star formation. O I, C II, and Si II-Si IV are observed with a mean outflow velocity langv _{out}rang = -60 km s⁻¹. We also detect faint fine-structure emission lines of singly ionized silicon for the first time in a low-

redshift starburst galaxy. These emissions have been seen previously in deep Lyman break galaxy surveys at $z \sim 3$. The Si II* lines are at the galaxy rest velocity, and they exhibit a quantitatively different line profile from the absorption features. These lines have a width of ≈ 75 km s⁻¹, too broad for pointlike emission sources such as the H II regions surrounding individual star clusters. The size of the Si II* emitting region is estimated to be ≈ 250 pc. We discuss the possibility of this emission arising in overlapping super star cluster H II regions, but find this explanation to be unlikely in light of existing far-UV observations of local star-forming galaxies. We suggest that the observed Si II* emission originates in a diffuse warm halo populated by interstellar gas driven out by intense star formation and/or accreted during a recent interaction that may be fueling the present starburst episode in KISSR242. Based on observations made with the NASA/ESA Hubble Space Telescope, obtained from the data archive at the Space Telescope Science Institute. STScI is operated by the Association of Universities for Research in Astronomy, Inc. under NASA contract NAS 5-26555.

245.03

Large-scale Shock-ionized and Photoionized Gas in M83: The Impact of Star Formation Sungryong Hong¹, D. Calzetti¹, M. A. Dopita², WFC3 SOC

¹University of Massachusetts at Amherst, ²Research School of Astronomy & Astrophysics, The Australian National University, Australia.

Exhibit Hall

We investigate the ionization structure of nebular gas in M83 using the line diagnostic diagram, $[SII](6716+6731A)/H\alpha$ vs. $[OIII](5007A)/H\beta$ with the newly available narrowband images from the Wide Field Camera 3(WFC3) of the Hubble Space Telescope(HST). We produce the diagnostic diagram on a pixel-by-pixel (0.2"×0.2") basis and compare it with several photo- and shock-ionization models. We select four regions from the center to the outer spiral arm and compare them in the diagnostic diagram. For the photo-ionized gas, we observe a gradual increase of the $log([OIII]/H\beta)$ ratios from the center to the spiral arm, consistent with the metallicity gradient from the center to the spiral arm, as the HII regions go from super solar abundance to roughly solar abundance. Using the diagnostic diagram, we separate the photo-ionized from the shock-ionized component of the gas. We find that the shockionized H α emission ranges from ~2% to about 15-20% of the total, depending on the separation criteria used. An interesting feature in the diagnostic diagram is an horizontal distribution around $log([OIII]/H\beta) \approx 0$. This shows a good fit with a shock-ionization model at 2.0 Z \odot metallicity and shock velocities in the range of 300 km/s to 400 km/s. A low velocity shock component, < 200 km/s, is also detected, and is located at the boundary between the outer ring and the spiral arm. The low velocity shock component can be due to 1) supernova remnants located nearby, 2) dynamical interaction between the outer ring and the spiral arm, 3) abnormal line ratios from extreme local dust extinction. This paper is based on Early Release Science observations made by the WFC3 Scientific Oversight Committee. We are grateful to the Director of the Space Telescope Science Institute for awarding Director's Discretionary time for this program.

245.04

The Physics of the Calorimeter Model in M82

Tova Yoast-Hull¹, J. Everett¹, J. S. Gallagher III¹, E. Zweibel¹

¹University of Wisconsin-Madison.

Exhibit Hall

The striking correlation between far-infrared and radio emission found in disk galaxies has led to a calorimetric model for galaxies. In this calorimeter model, all the energy input from supernovae is expended within the galaxy, so both the far-infrared and radio synchrotron emission from cosmic rays are proportional to the supernova rate. To determine how broadly the calorimeter model applies, we

examine the energy balance in the starburst galaxy M82: this galaxy's hyperactive star formation rate per unit area (100 times the Milky Way's mean value) provides a severe test of the calorimeter model. Using an empirical model for the M82 starburst zone, we determine confinement times of cosmic rays in the galaxy and the energy losses of primary and secondary cosmic rays, specifically accounting for pair production, ionization losses, and synchrotron emission. We also consider the role of a wind in the propagation and transport of the cosmic rays. The results are tested against the observed multiwavelength characteristics of M82.

245.05

Molecular Hydrogen in the Galactic Wind of M82

Joshua Fuchs¹, D. Rupke¹

¹Institute for Astronomy, University of Hawai'i ; Rhodes College. Exhibit Hall

A more complete understanding of the multiphase nature of galactic winds is necessary to constrain the dominant carriers of mass and energy. Recent studies of near-infrared lines of molecular hydrogen in the galactic wind of M82 have revealed that the warm H₂ is extended more than 3 kpc from the nucleus of the galaxy. This project used Gemini NIR spectroscopy to study the velocity structure of the warm molecular hydrogen, which in turn provides information on the dynamical importance of this newly-discovered, extended phase. We also present near-infrared shock diagnostics of the M82 wind. This work was conducted by a Research Experience for Undergraduates (REU) position at the University of Hawai'i's Institute for Astronomy and funded by the NSF.

245.06

Densitometry and Thermometry of Starburst Galaxies

Meredith A. MacGregor¹, J. G. Mangum²

¹Harvard University & NRAO, ²NRAO.

Exhibit Hall

The conditions that lead to the development of starburst regions within galaxies are not well understood. By combining observations of formaldehyde (H₂CO) and ammonia (NH₃), we present a more complete picture of the physical conditions within several known starburst galaxies. Observations of the 1_{10} - 1_{11} and 2_{11} - 2_{12} K-doublet transitions of H₂CO and the (1,1), (2,2), (4,4), and (2,1) transitions of NH₃ were taken using the Green Bank 100-m telescope. The ratio of the integrated intensities of the observed metastable levels of NH₃ was used to determine probable values of the kinetic temperatures in the starburst regions. Using these calculated kinetic temperature values to restrict Large Velocity Gradient modeling of the H₂CO lines allowed us to determine the best fit spatial and molecular column densities for a sample of six starburst galaxies. The variations among starburst galaxies are discussed in the context of the physical parameters determined in this study and available from the literature. This project was supported by the NSF/REU grant AST-0223851 and the National Radio Astronomy Observatory.

245.07

Mini-Spirals: Signatures of Galaxy Transformation

John S. Gallagher¹, K. Dellenbusch², A. Parker³

¹Univ. of Wisconsin, ²Bowling Green State University, ³Indiana University.

Exhibit Hall

Dissipative processes play a major role in controlling the growth of galaxies, particularly in producing their dense baryon dominated central regions. Observations exploring how baryons lose energy and angular momentum to allow gas to flow into the centers of galaxies therefore provide important windows into galaxy evolution. One such pathway is associated with the presence of small, gas-rich

disks. These features can be especially prominent in lower mass starburst galaxies, where they sometimes appear as remarkable miniature spirals. The compact starburst galaxies NGC 3928 (M_B = -18.6) and II Zw 168 (M_B = -21.4) are examples of this phenomenon, hosting high surface brightness inner disks with diameters of approximately 3 kpc and 5 kpc, respectively. Both disks display well developed spiral structure, and are embedded in larger diffuse stellar envelopes. Using a combination of data from the archives and our observations, we present basic physical characteristics of these two systems, which include spiral arms with widths of only ~100 pc, and utilize this information to investigate their unusual evolutionary states.

This research has been supported in part by grant NSF AST-0708967 and made use of the WIYN Observatory 0.9-m and 3.5-m telescopes.

245.08

GBT HI Observations Of The GOALS Luminous Infrared Galaxies

Diana Windemuth¹, D. T. Frayer², R. Maddalena²

¹Barnard College of Columbia University, ²NRAO.

Exhibit Hall

The Great Observatories All-sky LIRG Survey (GOALS) represents a sample of the most luminous infrared galaxies (LIRGs, L(IR)>1e11 L(Sun)) in the local Universe. LIRGs show enhanced starburst and AGN activity, typically related to interacting galaxies and merger events. We report on a new deep Green Bank Telescope (GBT) HI survey of all of the GOALS galaxies above a declination of -35 degrees (167 LIRGs in total). The observations were carried out in 2010 and were recently just completed. We discuss the preliminary analyses of the HI masses and the ratios of HI to stellar mass as a function of infrared luminosity and merger stage. This research was carried out at National Radio Astronomy Observatory (NRAO) Green Bank facility as part of the National Science Foundation (NSF) Research for Undergraduates (REU) program. The NRAO is a facility of the NSF operated under cooperative agreement by Associated Universities, Inc.

245.09

The Kinetic Temperature of Molecular Gas in Arp 220: Ammonia Observations with the ATCA and GBT Juergen Ott¹, C. Henkel², J. A. Braatz¹, A. Weiss²

¹National Radio Astronomy Observatory, ²Max-Planck-Institut fuer Radioastronomie, Germany. Exhibit Hall

Using the ATCA and GBT telescopes, we observed ammonia (NH3) in Arp 220, the nearest ultraluminous infrared galaxy merger. We detect all the inversion transitions from (1,1) through (6,6) in absorption against the bright radio continuum. The velocities indicate that the absorption emerges from the gas that encompasses both starburst nuclei. Ammonia is a very good thermometer for the molecular gas and we derive a kinetic temperature of 186+/-55 K. The profile of the ammonia (1,1) emission is unusually weak compared to the other inversion transitions, which may indicate an additional cold component that is masking the line profile.

245.10

VLBI Imaging of OH Satellite Lines in Arp220

Derek Felli¹, C. J. Salter², T. Ghosh², E. Momjian³

¹BYU, ²NAIC-Arecibo Observatory, Puerto Rico, ³NRAO.

Exhibit Hall

Arecibo single-dish spectra of Arp220 taken in 2003 revealed complex emission and absorption features in the OH satellite lines at 1612 and 1720 MHz. From these spectra, two velocity ranges are found where these lines are conjugate, while in a third both lines are in emission, with both being seen in absorption in a fourth. For a fuller understanding of the physical conditions leading to such behaviour in this

prototype ULIRG, the precise locations and structures of these individual features need to be know in order that detailed comparison can be made with existing high-resolution line and continuum studies of the object. Accordingly, VLBI observations with the EVN (including the Arecibo telescope) were taken of both satellite lines, and have recently been imaged. In this poster, we will present these images and the results and conclusions derived from them.

245.11

An All-stokes, All-line Survey Of OH Megamasers in Luminous Infrared Galaxies James McBride¹, C. Heiles¹

¹UC Berkeley.

Exhibit Hall

We present recent results from a survey of all known OH megamasers accessible to the Arecibo 300-m telescope. The survey is an extension of the work presented in Robishaw, Quataert, and Heiles (2008), measuring all four Stokes parameters for the main OH maser lines at 1667 and 1665 MHz and the satellite lines at 1612 and 1720 MHz. We compare the original observations of the sources presented in Robishaw et al. to reobservations of the same sources a few years later, and discuss evidence for variability. The linear polarization data may be used to place limits on and in some cases measure the Faraday rotation for the continuum synchrotron emission. We use the circular polarization data to measure the Zeeman splitting of maser lines. The Zeeman splitting is then used to measure the magnetic field in the masing regions. We connect the measured magnetic fields with the large scale properties of the Luminous Infrared Galaxies that play host to OH megamasers. Support for this work was provided in part by NSF grant AST-0908572.

245.12

Spitzer Spectroscopy of Two Lensed Star-forming Galaxies

Ross Fadely¹, S. S. Allam², A. J. Baker³, H. Lin², D. Lutz⁴, A. E. Shapley⁵, M. Shin⁶, J. Allyn Smith⁷, M. A. Strauss⁸, D. L. Tucker²

¹Haverford College, ²Fermi National Accelerator Laboratory:, ³Rutgers University, ⁴Max-Planck-Institut fur extraterrestrische Physik, Germany, ⁵University of California, Los Angeles, ⁶University of Michigan, ⁷Austin Peay State University, ⁸Princeton University.

Exhibit Hall

Presented are Spitzer/IRS spectra of two lensed UV-bright z~2 star-forming galaxies, SDSS J120602.09+514229.5 and SDSS J090122.37+181432.3. With the magnification provided by lensing, we study the rest-frame ~ 5 - 12 micron emission of the galaxies in greater detail than otherwise possible. We infer both targets are undergoing intense star-formation through the strong PAH emission seen at 6.2, 7.7, and 11.3 microns. In J1206, we detect rising continuum and significant [SIV] emission, indicating a moderately hard radiation field is powering the mid-IR luminosity. We use the strength of the [SIV] emission to infer a metallicity of Z ~ 0.5*Zsun in J1206, confirming existing measurements at optical wavelengths. For J0901, we find the strength of the PAH emission, shallow slope of the continuum, and the strength of optical [OIII] emission imply AGN energetics provide only a small fraction of the infrared luminosity. Through the ratio of [Ar III]/[Ar II], we also imply a metallicity of Z & gt; 1.3 Zsun for J0901. We highlight the importance of both optical and mid-IR spectroscopy in understanding the properties of high-redshift galaxies. This work is based on observations made with the Spitzer Space Telescope, which is operated by the Jet Propulsion Laboratory, California Institute of Technology under a contract with NASA. Support for this work was provided by NASA through two awards issued by JPL/Caltech.

Redshift Determination and 12CO Line Excitation Modeling for the Multiply-Lensed Submillimeter Galaxy SMM 1057+5730

Kimberly S. Scott¹, Z-Spec team, HerMES Consortium, IRAM PdBI team, CARMA team ¹Univ. Of Pennsylvania.

Exhibit Hall

We report a redshift of z=2.956 for SMM 1057+5730, a multiply-lensed sub-millimeter galaxy detected with Herschel/SPIRE in the HerMES Lockman-SWIRE field. With the 100 GHz instantaneous bandwidth of the Z-Spec instrument on the Caltech Submillimeter Observatory, we robustly identify the redshift of this source from the simultaneous detection of four 12CO emission lines (J = 7-6, J = 8-7, J = 9-8, and J = 10-9). Combining the measured line fluxes for these high-J transitions with the J = 3-2 and J = 5-4 line fluxes measured with CARMA and the IRAM PdBI, respectively, we model the physical properties of the molecular gas in this galaxy. We find that the full 12CO spectral line energy distribution is best described by warm, low-density gas (T ~ 400 K, n ~ $10^{2.7}$ cm⁻³). However, it is possible that the highest J transitions are radiatively excited by warm gas (potentially close to an AGN), or alternatively are tracing a small fraction of very dense gas in molecular cloud cores, which in either case a single gas component model would not describe the full SLED. Future observations of lower J transitions for this source will aid in distinguishing between these scenarios.

245.14

Z-Spec Measurements of CO Redshifts for Lensed Submillimeter Galaxies Discovered in the H-ATLAS Survey

Roxana E. Lupu¹, Z-Spec Team, ATLAS Consortium

¹Univ. of Pennsylvania.

Exhibit Hall

We present new observations from Z-Spec, a broadband 200 - 300 GHz spectrometer, of sub-millimeter bright lensed sources recently detected by the Herschel Astrophysical Terahertz Large Area Survey (H-ATLAS). Four out of five sources observed were detected in CO, and their redshifts measured using a new redshift finding algorithm that uses combinations of the signal-to-noise of all the lines falling in the Z-Spec bandpass to determine redshifts with high confidence, even in cases where the signal-to-noise in individual lines is low. Lower limits for the dust masses ($\sim a$ few 10⁸ M_{\odot}) and spatial extents (~ 1 kpc equivalent radius) are derived from the continuum spectral energy distributions, corresponding to dust temperatures between 54 and 69 K. The dust and gas properties, as determined by the CO line luminosities, are characteristic of dusty starburst galaxies, with star formation rates of $10^2 \cdot 10^3 \text{ M}_{\odot}/\text{yr}$. In the LTE approximation, we derive relatively low CO excitation temperatures (< 100 K) and optical depths (tau<1). Using a maximum likelihood technique, we perform a non-LTE excitation analysis of the detected CO lines in each galaxy to further constrain the bulk molecular gas properties. We find that the mid-J CO lines measured by Z-Spec localize the best solutions to either a high-temperature / low-density region, or a low-temperature / high-density region near the LTE solution, with the optical depth varying accordingly. Future observations of CO(1-0) or other molecular lines should help distinguish these scenarios and further illuminate the star-formation history of these galaxies.

Selecting 1<z<2 Lyman Break Galaxies the Swift Way

Antara Basu-Zych¹, A. Hornschemeier¹, E. Hoversten², C. Gronwall², B. Lehmer³ ¹Goddard Space Flight Center, ²Penn State University, ³Goddard Space Flight Center and Johns Hopkins

University.

Exhibit Hall

Designed to study gamma ray bursts, the Swift satellite has also ultraviolet and optical capabilities. In this study, we use the UVOT instrument aboard Swift to discover 1<z<2 Lyman break galaxies (LBGs). Using UVOT near-ultraviolet color selection, we select UV-dropouts in the Chandra Deep Field South (CDFS). We match the selected sources with available multi-wavelength data from ACS GOODS-South, MUSYC, and COMBO-17 to characterize spectral energy distributions and determine stellar masses, star formation rates (SFRs) and dust attenuation in these galaxies. Additionally, working with these multi-wavelength catalogs, we explore how the Swift UVOT selection of LBGs (and possibly the UV-dropout selection in general) might bias the final LBG sample. In this talk, I will present how the properties of the selected sample compare with other samples: z~3 LBGs, z<1 UV luminous galaxies, and other z=1-2 CDFS galaxies, and I will present the potential for using Swift to search for Lyman break galaxies.

246

Spiral Galaxies Poster Session *Exhibit Hall*

246.01

Bars and Nuclear Activity in S⁴G Galaxies Trisha Mizusawa¹, K. Sheth¹, T. Kim¹, S4G Team ¹NRAO.

Exhibit Hall

We present an analysis of bars and their relationship to nuclear activity in the Spitzer Survey of Stellar Structure in Galaxies (S4G) sample. S4G is a Spitzer Exploratory Science survey with IRAC to map the mass and stellar structure of 2,331 nearby (d < 40Mpc) galaxies to create an unprecedented data set for studies of structure formation during galaxy evolution. The focus of this research is to study the barred spiral population and to address the relationship between the bar-induced gas flow and nuclear activity in S4G galaxies.

246.02

A Survey Of Edge-on Disk Galaxies In The SDSS DR7 And Their Intrinsic Shape

Stefan J. Kautsch¹, R. W. Hillyer¹, N. McMahon¹

¹*Christopher Newport University.*

Exhibit Hall

We present a magnitude and size limited survey of edge-on disk galaxies in the Sloan Digital Sky Survey Data Release 7. The objects are classified into several distinct morphological Hubble types using an automated algorithm based upon bulge size and disk thickness. We detect a large fraction of bulgeless galaxies. This is in contrast to current theoretical models of galaxy formation and evolution in which the existence of pure disks cannot be fully explained. We also study the intrinsic thickness of those galaxies and find that a majority of the systems exhibit a red envelope. This feature can be explained as a potential signature of thick disks.

Chemical Abundance Pattern in Spiral Galaxy NGC 628 from Narrow-Band Photometry Dmitry Bizyaev 1

¹NMSU/APO.

Exhibit Hall

We consider a possibility of studying the two-dimensional gas abundances in relatively nearby galaxies using the narrow-band photometry. A face-on spiral galaxy NGC 628 was observed with a small 0.5-m telescope at the Apache Point Observatory in 11 narrow passbands. We centered them at the Balmer emission lines, at the strong lines of O, N, S, and interline continuum points. We derive the distribution of the dust extinction and chemical abundances across the whole disk of NGC 628. Accuracy of the method and possibility of optimization of the passbands number is considered. The project is partly supported by AAS Small Research grant.

246.04

The Super-Linear Slope Of The Spatially-resolved Star Formation Law In NGC 3521 And NGC 5194 (m51a)

Guilin Liu¹, J. Koda², D. Calzetti¹, M. Fukuhara³, R. Momose³

¹University of Massachusetts at Amherst, ²Stony Brook University, ³University of Tokyo, Japan. Exhibit Hall

We have conducted interferometric observations with CARMA and an OTF mapping with the 45-m telescope at NRO in the CO (1-0) emission line of NGC 3521. Combining these new data, together with similar data for M51a and archival SINGS H-alpha, 24um, THINGS H I and GALEX FUV data for both galaxies, we investigate the empirical scaling law that connects the surface density of star formation rate (SFR) and cold gas (the Schmidt-Kennicutt law) on a spatially-resolved basis, and find a super-linear slope when carefully subtracting the background emissions in the SFR image. We argue that plausibly deriving SFR maps of nearby galaxies requires the diffuse stellar/dust background emission to be carefully subtracted (especially in mid-IR). An approach to complete this task is presented and applied in our pixel-by-pixel analysis on both galaxies, showing that the controversial results whether the molecular S-K law is super-linear or basically linear is a result of removing or preserving the local background. In both galaxies, the power index of the molecular S-K law is super-linear (1.5-1.9) at the highest available resolution (230 pc), and decreases monotonically for decreasing resolution; while the scatter (mainly intrinsic) increases as the resolution becomes higher, indicating a trend for which the S-K law breaks down below some scale. Both quantities are systematically larger in M51a than in NGC 3521, but when plotted against the de-projected scale, they become highly consistent between the two galaxies, tentatively suggesting that the sub-kpc molecular S-K law in spiral galaxies depends only on the scale being considered, without varying amongst spiral galaxies. We obtaion slope=-1.1[log(scale/kpc)]+1.4 and scatter=-0.2 [scale/kpc]+0.7 through fitting to the M51a data, which describes both galaxies impressively well on sub-kpc scales. However, a larger sample of galaxies with better sensitivity, resolution and broader FoV are required to test these results.

246.05

X-ray Observations and the Nuclear Star Cluster in NGC 2139

Joseph C. Shields¹, T. Boeker², L. C. Ho³, H. W. Rix⁴, R. P. van der Marel⁵, C. J. Walcher⁶ ¹Ohio Univ., ²ESA, Netherlands, ³Carnegie Observatories, ⁴MPIA, Germany, ⁵STScI, ⁶AIP, Germany. Exhibit Hall

Compact star clusters found in the centers of galaxies tend to be dense, massive, and comprised of multiple generations of stars. The formation of such clusters may be linked to the formation of supermassive black holes in galaxy nuclei. X-rays provide one means of detecting a supermassive black

hole associated with a nuclear cluster. The Scd galaxy NGC 2139 has a compact star cluster at its center with unusual characteristics suggesting that it may be representative of the early evolution of nuclear star clusters. In this presentation we report Chandra Observatory results bearing on the presence of a central black hole and other sources undergoing accretion in NGC 2139.

246.06

The Arecibo Galaxy Environment Survey (AGES) - HI Observations of the Isolated Galaxy UGC 2082 Timothy M. Taber¹, R. Minchin², AGES

¹Vassar College, ²Arecibo Observatory.

Exhibit Hall

The Arecibo Galactic Environment Survey (AGES) is a 21-cm neutral hydrogen survey utilizing the Arecibo L-band Feed Array on the 305-m radio telescope at Arecibo Observatory. AGES uses a bandwidth of 100 MHz, allowing the detection of galaxies out to heliocentric velocities of ~20000 km/s. Many different galaxy environments are being examined in AGES including isolated galaxies, where one objective is to find possible low surface brightness companion galaxies.

The field surrounding isolated galaxy UGC 2082 was examined for this project, and 90 possible sources were found in the data cube. Of these, 46 are regarded as definite detections; the others will be reobserved with the L-Band Wide receiver at Arecibo Observatory in order to confirm their reality. Using optical data from the Sloan Digital Sky Survey and SuperCOSMOS the most likely optical counterparts have been chosen for each 21-cm source. 24 of the detected HI sources have no clear optical counterpart, many of these being dubious detections.

A very faint companion galaxy to UGC 2082 was found at a heliocentric velocity of 590 km/s. This source is located approximately 66.5 arcminutes north of UGC 2082 (which has a measured heliocentric velocity of 713 km/s). Using the published Tully-Fisher distance to UGC 2082 of 14.7 Mpc, the projected physical separation of the two galaxies is 284.4 kpc.

Another objective of AGES is to gain insight on the HI mass function and the large-scale structure of the universe. All of the detected sources in this data were plotted by right ascension or declination versus heliocentric velocity. These plots showed noticeable structure at both 5500 km/s and 11000 km/s. The Arecibo Observatory is part of the National Astronomy and Ionosphere Center, which is operated by Cornell University under a cooperative agreement with the National Science Foundation.

246.07

Discovery of the First Methanol Maser in M31

Claire Murray¹, L. Sjouwerman², Y. Pihlstrom³

¹Carleton College, ²National Radio Astronomy Observatory, ³University of New Mexico. Exhibit Hall

We present the detection of the first 6.7 GHz Class II methanol maser in the Andromeda galaxy (M31). This methanol maser was detected using the Very Large Array (VLA) in the fall of 2009 and confirmed using the new Expanded VLA in August 2010. We were unsuccessful in detecting a water maser at this location. The confirmed maser can be used for proper motion studies of M31, as was previously accomplished in IC10 and M33 using water masers. This would determine a pressing unknown in the evolution and dynamics of the Local Group: the transverse motion of M31. Our survey has revealed more candidate masers which yet need to be confirmed. Detecting more masers and using them in the proper motion measurements would allow for a more accurate determination of the three-dimensional velocity of M31 and a geometric distance to the galaxy. This research was supported by the Research Experience for Undergraduate Program of the National Science Foundation, and was completed at the National Radio Astronomy Observatory in Socorro, New Mexico.

Dark Matter Density Profiles Of Disk Galaxies: The Nuclear Spiral Connection Marc ${\rm Seigar}^1$

¹University of Arkansas at Little Rock.

Exhibit Hall

Hubble Space Telescope (HST) images have revealed that nuclear spiral structure exists in the centers of many disk galaxies. The morphology of this spiral pattern depends on the properties of the nuclear gravitational potential, and so it has been suggested that given an image of the nuclear spiral, it should be possible to determine the mass distribution of its host galaxy. Furthermore, the morphology can also reveal whether the spiral exists in a pseudo-isothermal dark matter potential or a cuspy dark matter potential. In this poster, we use HST images of the central regions of disk galaxies to measure the spiral arm pitch angle of nuclear spirals as a function of radius. From this we determine the best halo density models that describe the mass distributions in these galaxies.

246.09

A Comparison of Two Independent Techniques for Measuring Supermassive Black Hole Masses Ismaeel Ahdulla Akhlite Al-Baidhany¹, M. S. Seigar¹, P. Treuthardt¹, B. Davis², D. Kennefick², J. Kennefick², C. H. S. Lacy², M. Bentz³

¹University of Arkansas at Little Rock, ²University of Arkansas at Fayetteville, ³Georgia State University. Exhibit Hall

In this study we compare the masses of supermassive black holes (SMBH) in 35 galaxies estimated using reverberation mapping to those determined using the SMBH mass versus pitch angle relation. Both methods provide an independent determination of SMBH mass. We selected a sub-sample of nearly face-on spiral galaxies and used IRAF to determine the ellipticity and major-axis position angle in order to deproject the galaxy images to face-on. A two-dimensional Fast Fourier Transform was then applied to the deprojected images in order to measure the spiral arm pitch angles and, thereby, provide a SMBH mass estimate.

246.10

Chandra ACIS Survey of M33 (ChASeM33): Spectral and Timing Analysis of the 15 Brightest Sources Paul P. Plucinsky¹, R. Tuellmann¹, T. J. Gaetz¹, P. Challis¹, R. P. Kirshner¹, B. F. Williams², K. D. Kuntz³, ChASeM33 Team

¹Harvard-Smithsonian, CfA, ²University of Washington, ³Johns Hopkins University. Exhibit Hall

The Chandra ACIS Survey of M33 (ChASeM33) is the deepest X-ray survey to date of M33. ChASeM33 covers about 70% of the D25 isophote (R ~ 4.0 kpc) with a total exposure of 1.4 Ms. The source catalog includes 662 sources, reaching a limiting sensitivity of ~2.0e34 erg/s in the 0.35--8.0 keV energy band. There are fifteen sources in the catalog with more than 2,000 net counts, allowing detailed spectral and timing analyses to be conducted. We report here the results of fitting these spectra with multi-component disk blackbody, power-law, and/or thermal plasma models. We also report on the short-term (within an observation) and long-term (from one observation to another) variability of these sources. These X-ray spectral and timing results in conjunction with optical spectroscopy for some of the sources, allow us to classify the objects. Six of the sources are X-ray Binaries (3 certain/3 most likely), 3 are Supernova Remnants (all three certain), and 6 are Active Galactic Nuclei (3 certain/3 most likely). The faintest of these sources has a flux (0.35-8.0 keV) of ~3.5e-14 ergs/(s cm²) and an inferred luminosity of ~3.0e36 ergs/s (0.35-8.0 keV) at the distance of M33. We comment on the contribution of these ``background'' sources to studies of the X-ray source populations in galaxies. This work was supported by NASA grant NAS G06-7073A and NASA contract NAS8-03060.

The Molecular Gas in the Whirlpool Galaxy

Eva Schinnerer¹, A. Leroy², J. Pety³, G. Dumas¹, S. Meidt¹, D. Colombo¹, S. Garcia-Burillo⁴, A. Hughes⁵, C. Kramer³, H. Rix¹, K. Schuster³, T. Thompson⁶, A. Weiss⁷, S. Aalto⁸, N. Scoville⁹ ¹*MPIA, Germany,* ²*NRAO,* ³*IRAM, Spain,* ⁴*OAN, Spain,* ⁵*MPIA, Swinburne University, Germany,* ⁶*OSU,* ⁷*MPIfR, Germany,* ⁸*OSO,* ⁹*CalTech.*

Exhibit Hall

The nearby spiral galaxy M51 is a prime target for studying the properties of molecular gas in the environment of spiral arms. Our recent analysis of multi-transition data from the OVRO millimeter interferometer of two selected regions of its prominent gas spiral arms shows that Giant Molecular Clouds (GMCs) residing in the spiral arms are very similar to their cousins found in the Milky Way. In addition, the conversion factor from CO line velocity to molecular gas mass is very similar to values derived for Galactic GMCs.

The recently finished PdBI Arcsecond Whirlpool Survey (PAWS) imaged the GMCs population of Giant Molecular Clouds (GMCs) in the central 8 kpc disk of M51 at an unprecedented resolution of 45pc using the PdBI and 30m instruments. First results from this IRAM Large Program regarding the properties of GMCs, their evolution and relation to star forming sites within M51's impressive spiral arms will be presented.

246.12

The Structure Of The Dust Extinction In M51: Where Are The GMCs?

Michael W. Regan¹, R. Chandar², B. C. Whitmore¹

¹STScl, ²University of Toledo.

Exhibit Hall

We present an HST NICMOS mosaic of M51 taken with the F160W (H-band) filter. We combine this near-infrared image with a optical ACS image to create a high resolution image of the dust extinction in M51. The high signal to noise and resolution of this color map allows us to investigate the morphology of the interstellar medium in M51 with a spatial dynamic range that reveals structures ranging in size from ~10 pc to a kiloparsec.

The color map shows that the majority of the dust in M51 is distributed in linear structures, either in the spiral arm dust lanes or in one of the many spurs that connect to the spiral arm dust lanes. What is striking is the difference in this morphology and the millimeter interferometer maps of M51 which show the molecular gas concentrated into giant molecular clouds.

246.13

On the Relationship Between HI Disks and Dark Matter

Gerhardt R. Meurer¹, Z. Zheng²

¹University of Western Australia / ICRAR, Australia, ²The Johns Hopkins University. Exhibit Hall

Our best dynamical tracer for dark matter (DM) in galaxies are extended HI dominated disks. Indeed from the late 1970's it has been noted that the HI column density in extended HI disks often is nearly a linear tracer of the projected DM surface density. This coincidence has puzzled researchers. It has lead some to posit that the DM is in the disk, and hence may be disipative rather than non-interacting as in the standard Cold Dark Matter scenario. Others have pointed out that the MOND scenario would cause extended disks to produce rotation curves which could be interpreted as DM halos with a scaled up mass density. Here we argue that this phenomenon results from viscous disk evolution which will produce extended HI disks with mass profiles resembling the nearly isothermal halos they are embedded in.

HERACLES: The HERA CO-Line Extragalactic Survey

Adam K. Leroy¹, F. Walter², A. Schruba², F. Bigiel³, K. Foyle², HERACLES team

¹National Radio Astronomy Observatory, ²Max Planck Institute for Astronomy, Germany, ³UC Berkeley. Exhibit Hall

We present the HERA CO-Line Extragalactic Survey (HERACLES) --- an IRAM Large Program that mapped CO 2-1 emission from 47 nearby star-forming galaxies. Building on the THINGS VLA HI survey, Spitzer's SINGS survey, the GALEX Nearby Galaxy Atlas, HERACLES offers the chance to study the star formating interstellar medium in a broad context. We will present the full HERACLES data set for the first time, highlighting a full quarter-square-degree map of the nearby large spiral galaxy M101. We will also describe recent results studying molecular gas in the outer parts of spiral galaxies; relating HI, H2, dust, and star formation on small scales; and measuring the arm-interarm contrast in CO, HI, and SFR tracers.

246.15

Determination of Resonance Locations in the Barred Spiral Galaxy, NGC 613

Amber Sierra¹, M. S. Seigar¹, P. Treuthardt¹, I. Puerari²

¹University of Arkansas at Little Rock, ²Instituto Nacional de Astrofisica, Optica y Electronica, Mexico. Exhibit Hall

NGC 613 is a barred spiral galaxy (Hubble type SBbc) in the Southern Hemisphere. As part of the Carnegie-Irvine Nearby Galaxies Survey (CINGS), we have obtained good-quality B and I band images of this galaxy. We take Fourier transforms along radial cuts in both the B and I band galaxies and compare the phase angles as a function of radius in the two wavebands. The radius at which the B band phase angle and the I band phase angle cross indicates the location of the corotation radius. We compare this with previously determined locations of the corotation radius from sticky particle simulations and from morphological arguments.

246.16

The Bulge, Disk and Halo Components of Disk Galaxies: Kinematic vs. Photometric Decomposition Jacqueline E. McCleary¹, F. Governato², N. P. Vogt¹, A. M. Brooks³

¹New Mexico State University, ²University of Washington, ³California Institute of Technology. Exhibit Hall

We have analyzed surface brightness maps for disk galaxies formed in recent GASOLINE hydrodynamical cosmological simulations. To better understand stellar mass distributions, we directly compared classic photometric decomposition techniques, based on light profiles, with a kinematic decomposition based on particle positions and velocities. These galaxies exhibit masses, structural parameters, and colors typical of early type spirals, and so are excellent proxies for observed spiral galaxies. Surface brightness profiles were generated to model the light distributions in SDSS, HST ACS, and Spitzer IRAC bands. These images are based on local star formation histories and include a detailed treatment of light reprocessing by dust based on the 3D distribution of stars, gas and metals. Photometric bulge/disk decompositions and estimates of disk scale lengths were performed using the GALFIT modelling tool. Kinematic decompositions were made directly from simulation outputs and use the ratio of each stellar particle's angular momentum to the momentum of the co-rotating circular orbit, as well as particle binding energy, to assign it to either bulge, pseudo-bulge, disk or halo components.

Radial surface brightness profiles are commonly used to understand the underlying mass distribution of galaxies, and to provide insight into their formation and evolution. In the case of disk-dominated galaxies, such surface brightness profiles are typically described by a spheroidal bulge and an exponential disk; however disk galaxies are more dynamically complex systems than might be suggested by simple bulge and disk decompositions. We found that the photometrically identifed bulge often

consists of a combination of a kinematically identifed non-rotating, spherical, classic bulge made of old stars plus inner disk stars, and a rotating, flattened pseudo-bulge. This suggests that many photometric decompositions of disk galaxies may overestimate bulge stellar mass, and thus systematically underestimate the importance of the disk component at redshifts z > 0.5.

246.17

Resolved Stellar Populations In 50 Regions In M83

Hwihyun Kim¹, B. C. Whitmore², R. Chandar³, C. C. Kaleida¹, A. Saha⁴, R. A. Windhorst¹, WFC3 SOC ¹Arizona State University, ²STScI, ³Univ. of Toledo, ⁴NOAO.

Exhibit Hall

Color-magnitude diagrams (CMDs) of resolved stars are the most powerful diagnostic tool to understand stellar evolution and star formation history of a galaxy in detail. By comparing stellar evolution models to observations in CMDs, we are able to determine approximate ages of individual stellar populations in galaxies. However, in some regions with recent star-forming activity, stellar populations are partially obscured by dust. Applying a single extinction correction value often results in either over- or underestimate of the ages of individual stars.

We present a multi-wavelength photometric study of resolved stars in M83 from the HST WFC3/UVIS observations using four filters - F336W, F438W, F555W, and F814W - to measure colors and, given the known distance (4.5 Mpc) to M83, intrinsic luminosities of ~10,000 stars. We selected 50 regions in a spiral arm and inter-arm areas of M83, and categorized them based on their H α morphology. To determine ages of stellar populations, we combined the CMDs and the color-color diagrams with the Padova isochrones and also constrain the spatial variation of dust extinction in each region. We correct for Galactic foreground extinction and for the extinction towards each individual star internal to M83, resulting in improved stellar age estimates from isochrone fitting on CMDs. We find that age distributions of resolved stellar populations in 50 regions agree with blue-to-red star ratios, and with ages of clusters in their vicinity.

This work is based on Early Release Science observations made by the WFC3 Scientific Oversight Committee. We are grateful to the Director of the Space Telescope Science Institute for awarding Director's Discretionary time for this program.

246.18

The Arecibo Zone of Avoidance Survey

Travis P. McIntyre¹, P. A. Henning², R. Minchin³, E. Momjian⁴

¹Arecibo Observatory, The University of New Mexico, ²The University of New Mexico, ³Arecibo Observatory, ⁴NRAO.

Exhibit Hall

The Arecibo Zone of Avoidance survey is searching for 21cm emission from neutral hydrogen in galaxies located behind the plane of the Milky Way. The goal of the survey is to discover nearby galaxies which are undetectable at optical and infrared wavelengths because of high Galactic extinction and confusion. The survey will map out the nearby mass distribution and connect large scale structure across the zone of avoidance. It will also contribute to our understanding of the neutral hydrogen mass function. This poster will present the status of the survey. Observations, data reduction, and analysis are ongoing. The majority of the detections have been newly discovered sources.

246.19 **The WSRT HALOGAS survey George H. Heald**¹, HALOGAS Team ¹ASTRON, Netherlands.

Exhibit Hall

We present the HALOGAS (Hydrogen Accretion in LOcal GAlaxieS) survey. This is the first systematic investigation of cold gas accretion in nearby spiral galaxies to date. It consists of deep (120 hours) WSRT observations of 22 edge-on and moderately-inclined nearby galaxies. Using these data we are able to detect neutral hydrogen down to a column density of about 10¹⁹ cm⁻², and characterise the faint extraplanar and anomalous-velocity neutral gas with excellent spatial and velocity resolution. HALOGAS data also allow us to study the disc structure and dynamics in unprecedented detail for a sample of this size. Observations carried out so far show a variety of HI properties, ranging from accretion of (and interaction with) satellite galaxies to filaments possibly caused by star formation in the disc. The detected amount of anomalous gas indicative of accretion episodes varies significantly from galaxy to galaxy. This suggests that accretion of neutral gas from the ambient medium is a rather episodic process. A number of companion posters present first results on the modelling of some of the observed galaxies and on observations at other wavelengths which complement our 21 cm data.

246.20

The Halogas Project: HI Observations Of NGC 1003

Richard J. Rand¹, J. Allan², G. Heald³, G. Jozsa³

¹Univ. of New Mexico, ²Macalester College, ³ASTRON, Netherlands.

Exhibit Hall

We present deep neutral hydrogen observations of the nearby spiral galaxy NGC 1003, obtained as part of the Westerbork Hydrogen Accretion in LOcal GAlaxieS (HALOGAS) Survey currently being performed with the Westerbork Synthesis Radio Telescope (WSRT). Our data are sensitive enough to detect and study both faint diffuse neutral hydrogen gas, as well as discrete accreting gas clouds. We have performed careful tilted-ring modeling of NGC 1003, which shows that it is nearly edge-on, and has a significant warp. The HI disk is both thick (scale height ~ 1 kpc) and radially extended (4-5 times larger than the optical disk). We also present the results of our analysis of the extraplanar gas cloud population in this galaxy. We detect two discrete clouds in the halo of NGC 1003, both with HI masses of about two hundred thousand solar masses, and a larger extraplanar gas complex with an HI mass of about two million solar masses. These extraplanar gas features are analogous to high- and intermediate-velocity clouds around the Milky Way. We discuss the implications of these features for the accretion history of NGC 1003.

246.21

Kinematics of Ionized Gas in Edge-on HALOGAS Galaxies

Catharine J. Wu¹, R. Walterbos¹, R. Rand², R. Benjamin³, G. Heald⁴, HALOGAS Team ¹New Mexico State University, ²University of New Mexico, ³University of Wisconsin - Whitewater, ⁴Netherlands Institute for Radio Astronomy, Netherlands. Exhibit Hall

Extra-planar gas generally shows a decrease in rotational velocity with increasing height above the disk. It can originate from disk-halo cycling driven by star formation in the disk or from infalling gas clouds. Studies at optical and radio wavelengths suggest that a combination of the two is the most likely scenario. Our goal is to measure velocity gradients of the ionized gas in a large number of halos, which can then be used as a constraint for models of the origin of halo gas. Because we are observing in optical, our measurements are likely not affected by warps which generally occur further out in radial

distance. Our targets are drawn from a well-defined sample and are also a subset of the HALOGAS survey, which is investigating cold gas accretion in spiral galaxies with deep WSRT observations. We restrict our targets to edge-on galaxies, and our data provide an optical complement to HALOGAS data. We perform our observations using a multi-slit spectroscopic setup on the ARC 3.5m telescope. Arranging the slits parallel to the minor axis allows us to measure velocities of H-alpha emitting gas as a function of height above the plane in 11 radial distance bins in a single exposure. Our field of view is 3.75' x 4', and our total exposure time for a typical field is 6-8 hours. We present our ionized halo gas velocities for three nearby, edge-on galaxies and show a comparison with HI data.

246.22

The HALOGAS Project: HI Observations Of NGC 5055

Maria Patterson¹, R. Walterbos¹, G. Heald², G. Jozsa², L. Zschaechner³, R. Rand³, D. Thilker⁴, HALOGAS Team

¹New Mexico State University, ²Netherlands Institute for Radio Astronomy (ASTRON), Netherlands, ³University of New Mexico, ⁴Johns Hopkins University.

Exhibit Hall

We present deep neutral hydrogen observations of the nearby spiral galaxy NGC 5055 as part of the Westerbork Hydrogen Accretion in LOcal GAlaxieS (HALOGAS) survey currently being performed with the Westerbork Synthesis Radio Telescope (WSRT). The HALOGAS survey aims to investigate cold gas accretion in a sample of 22 neutrally-selected nearby spiral galaxies with 120 hours of integrated observation time for each target. The data are sensitive enough to study faint neutral hydrogen in the galaxy outskirts and to search for halogas and possible accreting gas clouds. The galaxy NGC 5055 is a moderately-inclined SAbc galaxy in the sample with a large pronounced warp of the extended gaseous disk and a declining rotation curve outside of the optical radius. We present an analysis of the new HI observations of this galaxy based on a tilted ring analysis and on more detailed modeling and visualization of the 3-D HI distribution and kinematics. We also discuss the relation between star formation in the faint outer disk spiral arms by comparison of the HI with GALEX and other star formation tracers.

246.23

The HALOGAS Project: HI Observations Of NGC 4244 And NGC 4565

Laura Zschaechner¹, R. J. Rand¹, G. H. Heald², G. Gentile³, HALOGAS Team ¹University of New Mexico, ²ASTRON, Netherlands, ³Universiteit Gent, Belgium. Exhibit Hall

We present models of the distribution and kinematics of HI in NGC 4244 and NGC 4565, two nearby spiral galaxies observed as part of the Westerbork Hydrogen Accretion in LOcal GAlaxieS (HALOGAS) survey. These models focus on the potential existence of extraplanar gas in the form of a halo as well as the presence of a negative gradient in rotational velocity upward from the plane of the disk (a lag). Insight concerning such information may help to better understand the prevalence as well as origins of halos in spiral galaxies, specifically whether they are a result of outflow from the disk, accretion from external sources, or a combination of the two. Models of NGC 4244 yield strong evidence against the presence of a halo and instead favor a warp along the line of sight as an explanation for the observed thickening of the disk. We do detect a lag which decreases in magnitude radially outward from the center of the disk such that the lag in the outermost parts of the disk is substantially shallower than that near the center. These models are based on deeper observations as well as improved modeling techniques and thus differ somewhat from past models of NGC 4244. Previous efforts to model NGC 4565 from data taken prior to the HALOGAS survey indicate a flare as well as a potential lag. We will refine these models using our deeper observations.

247

The Center for Astronomy Education (CAE) Collaboration of Astronomy Teaching Scholars (CATS) Program: A Year-Three Update Poster Session *Exhibit Hall*

247.01

The Center for Astronomy Education (CAE) and Our NSF CCLI Phase-III Collaboration of Astronomy Teaching Scholars (CATS) Program: A Year-Three Update on Our Community-Based Model for Astronomy Education Research

Gina Brissenden¹, C. D. Impey², E. E. Prather¹, K. M. Lee³, Collaboration of Astronomy Teaching Scholars (CATS)

¹Center for Astronomy Education (CAE), Steward Observatory, Univ. of Arizona, ²Steward Observatory, Univ. of Arizona, ³Univ. of Nebraska, Lincoln.

Exhibit Hall

The Center for Astronomy Education (CAE) has been devoted to improving teaching & learning in Astro 101 by creating research-validated curriculum & assessment instruments for use in Astro 101 & by providing Astro 101 instructors professional development opportunities to increase their pedagogical content knowledge & instructional skills at implementing these curricula & assessment materials. To create sustainability and further expand this work, CAE, in collaboration with other national leaders in astronomy education & research, developed the Collaboration of Astronomy Teaching Scholars (CATS) Program. The primary goals of CATS are to: 1) increase the number of Astro 101 instructors conducting fundamental research in astronomy education; 2) increase the amount of research-validated curriculum and assessment instruments available for use in Astro 101; and 3) increase the number of people prepared to develop and conduct their own CAE Teaching Excellence Workshops. Our year-three research updates include a longitudinal look at professional development and expanded professional development opportunities; new instructional tools and curriculum; learning gains related to Citizen Science and cosmology; and an expanded look at our LSCI study. To learn more about our CAE/CATS project, visit this and the other posters in our session.

This material is based upon work supported by the National Science Foundation under Grant No. 0715517, a CCLI Phase III Grant for the Collaboration of Astronomy Teaching Scholars (CATS). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. In addition, we would like to thank Michael Greene and JPL's NASA Exoplanet Public Engagement Program (EXEP) for their continued support.

247.02

Using Classical Test Theory and Item Response Theory to Evaluate the LSCI

Wayne M. Schlingman¹, E. E. Prather¹, Collaboration of Astronomy Teaching Scholars (CATS) ¹Center for Astronomy Education (CAE), Steward Observatory, Univ. of Arizona. Exhibit Hall

Analyzing the data from the recent national study using the Light and Spectroscopy Concept Inventory (LSCI), this project uses both Classical Test Theory (CTT) and Item Response Theory (IRT) to investigate the LSCI itself in order to better understand what it is actually measuring. We use Classical Test Theory to form a framework of results that can be used to evaluate the effectiveness of individual questions at measuring differences in student understanding and provide further insight into the prior results presented from this data set. In the second phase of this research, we use Item Response Theory to form a theoretical model that generates parameters accounting for a student's ability, a question's

difficulty, and estimate the level of guessing. The combined results from our investigations using both CTT and IRT are used to better understand the learning that is taking place in classrooms across the country. The analysis will also allow us to evaluate the effectiveness of individual questions and determine whether the item difficulties are appropriately matched to the abilities of the students in our data set. These results may require that some questions be revised, motivating the need for further development of the LSCI. This material is based upon work supported by the National Science Foundation under Grant No. 0715517, a CCLI Phase III Grant for the Collaboration of Astronomy Teaching Scholars (CATS). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

247.03

Improvements in Students' Understanding from Increased Implementation of Active Learning Strategies

Melissa N. Hayes-Gehrke¹, E. E. Prather², A. L. Rudolph³, Collaboration of Astronomy Teaching Scholars (CATS)

¹Univ. of Maryland, ²Center for Astronomy Education (CAE), Steward Observatory, Univ. of Arizona, ³California State Polytechnic Univ.

Exhibit Hall

Many instructors are hesitant to implement active learning strategies in their introductory astronomy classrooms because they are not sure which techniques they should use, how to implement those techniques, and question whether the investment in changing their course will really bring the advertised learning gains. We present an example illustrating how thoughtful and systematic implementation of active learning strategies into a traditionally taught Astro 101 class can translate into significant increases in students' understanding. We detail the journey of one instructor, over several years, as she changes the instruction and design of her course from one that focuses almost exclusively on lecture to a course that provides an integrated use of several active learning techniques such as Lecture-Tutorials and Think-Pair-Share questions. The students in the initial lecture-only course achieved a low normalized gain score of only 0.2 on the Light and Spectroscopy Concept Inventory (LSCI), while the students in the re-designed learner-centered course achieved a significantly better normalized gain of 0.43.

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247.04

Overcoming Common Conceptual and Reasoning Difficulties in Cosmology: A Lecture-Tutorial Approach

Edward E. Prather¹, C. S. Wallace², D. Duncan²

¹Center for Astronomy Education (CAE), Steward Observatory, Univ. of Arizona, ²Dept. of Astrophysical & Planetary Sciences, Univ. of Colorado at Boulder.

Exhibit Hall

For the past two years, we have conducted fundamental research into Astro 101 students' conceptual and reasoning difficulties in cosmology. To date, we have analyzed the responses of over 2000 students from institutions across the United States to questions on the Big Bang, the expansion and evolution of

the universe, and the evidence for dark matter. Our findings have helped guide the development of a new suite of cosmology Lecture-Tutorials to help students overcome their conceptual and reasoning difficulties. We discuss naïve ideas Astro 101 students have with several cosmology topics and provide evidence that the new Lecture-Tutorials help students achieve larger learning gains than is achieved by lecture alone. This material is based upon work supported by the National Science Foundation under Grant No. 0833364 and Grant No. 0715517, a CCLI Phase III Grant for the Collaboration of Astronomy Teaching Scholars (CATS). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

247.05

Assessment Of The Effect Of Participation In Zooniverse Projects On Content Knowledge

Sebastien Cormier¹, E. E. Prather¹, G. Brissenden¹, C. Lintott², P. L. Gay³, J. Raddick⁴, Collaboration of Astronomy Teaching Scholars (CATS)

¹Center for Astronomy Education (CAE), Steward Observatory, Univ. of Arizona, ²Adler Planetarium/Univ. of Oxford, ³Southern Illinois Univ. Edwardsville/Astrosphere New Media Association, ⁴Johns Hopkins Univ. Exhibit Hall

The citizen science projects developed by Zooniverse afford volunteers the opportunity to contribute to scientific research in a meaningful way by interacting with actual scientific data. We created two surveys to measure the impact that participation in the Galaxy Zoo and Moon Zoo citizen science projects has on user conceptual knowledge. The Zooniverse Astronomy Concept Survey (ZACS) was designed to assess Galaxy Zoo user understanding of concepts related to galaxies and how their understanding changed through participation in classifying galaxies. The Lunar Cratering Concept Inventory (LCCI) was designed to measure the impact of the Moon Zoo activities on user knowledge about lunar craters and cratering history. We describe how the surveys were developed and validated in collaboration with education researchers and astronomers. Both instruments are administered over time to measure changes to user conceptual knowledge as they gain experience with either Galaxy Zoo or Moon Zoo. Data collection has already begun and in the future we will be able to compare survey answers from users who have classified, for example, a thousand galaxies with users who have only classified ten galaxies. This material is based upon work supported by the National Science Foundation under Grant No. 0715517, a CCLI Phase III Grant for the Collaboration of Astronomy Teaching Scholars (CATS). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation and the Sloan Digital Sky Survey III Education and Public Outreach Program.

247.06

Student Practices, Learning, and Attitudes When Using Computerized Ranking Tasks

Kevin M. Lee¹, E. E. Prather², Collaboration of Astronomy Teaching Scholars (CATS) ¹Univ. of Nebraska, Lincoln, ²Center for Astronomy Education (CAE), Steward Observatory, Univ. of Arizona.

Exhibit Hall

Ranking Tasks are a novel type of conceptual exercise based on a technique called rule assessment. Ranking Tasks present students with a series of four to eight icons that describe slightly different variations of a basic physical situation. Students are then asked to identify the order, or ranking, of the various situations based on some physical outcome or result. The structure of Ranking Tasks makes it difficult for students to rely strictly on memorized answers and mechanical substitution of formulae. In addition, by changing the presentation of the different scenarios (e.g., photographs, line diagrams, graphs, tables, etc.) we find that Ranking Tasks require students to develop mental schema that are more flexible and robust.

Ranking tasks may be implemented on the computer which requires students to order the icons through drag-and-drop. Computer implementation allows the incorporation of background material, grading with feedback, and providing additional similar versions of the task through randomization so that students can build expertise through practice. This poster will summarize the results of a study of student usage of computerized ranking tasks. We will investigate 1) student practices (How do they make use of these tools?), 2) knowledge and skill building (Do student scores improve with iteration and are there diminishing returns?), and 3) student attitudes toward using computerized Ranking Tasks (Do they like using them?).

This material is based upon work supported by the National Science Foundation under Grant No. 0715517, a CCLI Phase III Grant for the Collaboration of Astronomy Teaching Scholars (CATS). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

247.07

Do You Need a Textbook to Teach Astro 101?

Alexander L. Rudolph¹, Collaboration of Astronomy Teaching Scholars (CATS)

¹California State Polytechnic Univ.

Exhibit Hall

During educational sessions at astronomy meetings, especially during Center for Astronomy Education (CAE) Teaching Excellence workshops, which I have attended and now help present, one of the questions everyone wants to discuss is which textbook to use to teach Astro 101 classes (general education astronomy courses for non-science majors). Some instructors have a favorite. Others will claim that they are all the same and that it doesn't matter.

Increasingly, however, the discussions turn to the question of whether any textbook is needed at all. Some of this discussion has been driven by the increase in the use of interactive learning strategies such as Think-Pair-Share questions, Lecture-Tutorials, and Ranking Tasks. These activities provide students a learning modality very different from the traditional lecture supplemented by homework, and raises the question of whether the learning that takes place during such interactive activities is enough to teach students what we wish them to know about astronomy.

I had been teaching an Astro 101 class for almost three years using a full suite of interactive learning strategies, when I decided to teach it without requiring the students to purchase a textbook. Comparison of test scores before and after this change shows that there is no statistical difference in student achievement whether a textbook is required or not. Details on the course and methodology used to reach this conclusion will be presented.

This work is supported by the National Science Foundation under Grant No. 0847170, a PAARE Grant for the Calfornia-Arizona Minority Partnership for Astronomy Research and Education (CAMPARE), and Grant No. 0715517, a CCLI Phase III Grant for the Collaboration of Astronomy Teaching Scholars (CATS). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.

247.08

Burning Down the Wall: Questions Commonly Asked by Astro 101 Instructors During CAE Workshops Jacqueline Laird¹, G. Brissenden¹, E. E. Prather¹, Collaboration of Astronomy Teaching Scholars (CATS) ¹Center for Astronomy Education (CAE), Steward Observatory, Univ. of Arizona. Exhibit Hall

The Center for Astronomy Education (CAE), as part of JPL's NASA Exoplanet Public Engagement Program (ExEP), has been conducting Teaching Excellence Workshops all across the country since 2004. Nearly

two thousand current and future astronomy instructors have participated in these workshops. During these highly interactive professional development experiences, participants are given the opportunity to ask anonymous questions to the workshop leaders by writing a question down on a sticky note and placing it on a sheet of paper identified as "The Wall of Burning Questions." These "Burning Questions" are read aloud and answered by workshop leaders throughout the course of the workshop. Here we present an overview of common themes of questions workshop participants ask, as well as an analysis of the depth of pedagogical content knowledge these questions represent. This material is based upon work supported by the National Science Foundation under Grant No. 0715517, a CCLI Phase III Grant for the Collaboration of Astronomy Teaching Scholars (CATS). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. In addition, we would like to thank Michael Greene and JPL's NASA Exoplanet Public Engagement Program (ExEP) for their continued support.

247.09

Increasing the Availability of Professional Development Opportunities through the Center for Astronomy Education (CAE) Regional Teaching Exchanges

Michael C. Lo Presto¹, G. Brissenden², A. D. Forestell³, R. S. French⁴, J. Lutz⁵, D. L. Martino⁶, W. L. Powell, Jr.⁷, P. E. Robinson⁸, A. L. Rudolph⁹, Collaboration of Astronomy Teaching Scholars (CATS) ¹Henry Ford Community College, ²Center for Astronomy Education (CAE), Steward Observatory, Univ. of Arizona, ³SUNY New Paltz, ⁴MiraCosta College, ⁵Univ. of Washington, ⁶Santiago Canyon College, ⁷Texas Lutheran Univ., ⁸Westchester Community College, ⁹California State Polytechnic Univ. Exhibit Hall

The Center for Astronomy Education (CAE), as part of JPL's NASA Exoplanet Public Engagement Program (ExEP), has been conducting Teaching Excellence Workshops all across the country since 2004. Nearly two thousand current and future astronomy instructors have participated in these workshops. To increase the availability of professional development opportunities for past workshop participants, as well as to foster a sense of community amongst geographically linked current and future Astro 101 instructors, we created CAE Regional Teaching Exchanges. Our Exchanges are coordinated by CATS Fellows who are regional experts from the broader CAE community. Our first Regional Exchange was held in 2005, and our newest Exchange region has just been created.

We report on the increased availability of professional development through our CAE Regional Teaching Exchanges, the many flavors our Exchanges take on, as well as lessons learned.

This material is based upon work supported by the National Science Foundation under Grant No. 0715517, a CCLI Phase III Grant for the Collaboration of Astronomy Teaching Scholars (CATS). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. In addition, we would like to thank Michael Greene and JPL's NASA Exoplanet Public Engagement Program (ExEP) for their continued support.

247.10

A New Approach to Delivering Astronomy Content Online

Kevin Hardegree-Ullman¹, C. Impey¹, A. Patikkal¹, B. Guvenen¹, A. Srinathan¹, M. Swatzell¹

¹University of Arizona.

Exhibit Hall

We have created an online application that clusters the entire Wikipedia and provides a new and useful search engine and interface for the widely used internet knowledge medium. We used an existing open source search engine, and modified it with our own algorithms to give the best possible results from a search query. Astronomy served as the primary test subject in which we analyzed our clustering

algorithms. We found that once our algorithms were working well for clustering astronomy articles, similarly decent results were obtained in other academic test subjects. This tool will be implemented and tested for effectiveness in introductory astronomy courses at The University of Arizona. In addition to Wikipedia, we are using our tool to cluster an online astronomy textbook and astronomy lecture video content. Our clustering and search algorithms have potential to be applied to many other subjects and online content. We believe that our tools will be beneficial to students and help them easily navigate and see correlation between subjects within the compendium of knowledge online. This material is based upon work supported by the National Science Foundation under Grant No. 0715517, a CCLI Phase III Grant for the Collaboration of Astronomy Teaching Scholars (CATS). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

248

Astronomy Education and Research in Grades K-12 Poster Session Exhibit Hall

248.01

Researching Effective Methods for Teaching the Phases of the Moon

Heather Jones¹, E. G. Hintz¹, M. J. Lawler¹, R. Davies¹

¹Brigham Young Univ..

Exhibit Hall

This project investigates the effectiveness of several commonly used methods for teaching the phases of the moon to fifth and sixth grade students. Common teaching methods investigated are the use of diagrams, animations, modeling/kinesthetics, and direct observations of the moon (in a planetarium). Students are taught about the phases of the moon using one or more of these methods. Their understanding of why the phases of the moon occur is measured by a pre and post assessment. With this data, the effectiveness of each teaching method is evaluated individually and comparatively. In addition, the method's capacity to discourage the common eclipse misconception about moon phases is also investigated. The results of this research will be useful to teachers and provide foundational data for future research in the development of educational planetarium shows.

248.02

Talk The Talk, A Double E/PO Challenge

Rick Kang¹

¹Oregon Astrophysics Outreach-Pine Mtn. Obs.. Exhibit Hall

We use many ordinary words in the process of science, such as Model, Empirical, Correlate, Characteristic, Proportion, Ratio, Noise, Precision, Accuracy, Speculation, and Hierarchy.

1. Perhaps we should take some time to clarify the scientific meaning of these words for the public, particularly for students:

a. Promotes understanding of what we are working on.

b. Promotes understanding of the scientific process, improving science literacy.

2. There is an ongoing opportunity to offer vocabulary to students, particularly in K-8 classrooms where there is currently great emphasis on reading to meet standards. The additional reading time is often at the expense of science time. How can we effectively include science vocabulary within the reading? I propose starting a forum to discuss these issues.

The Edelman Galileoscope Education Program: A Collaboration Among Professional Societies Stephen M. Pompea¹, K. B. Marvel², R. T. Fienberg², D. N. Arion³, A. Herrold⁴, B. Kruse⁵, R. T. Sparks¹, C. Dugan¹

¹NOAO, ²American Astronomical Society, ³Carthage Collage, ⁴National Earth Science Teachers Association, ⁵Astronomical Society of the Pacific.

Exhibit Hall

The Edelman Galileoscope Education Program is an ongoing national effort to provide K-12 teachers with Galileoscope refractor kits and the proper training to use them effectively for teaching scientific concepts and observational skills. As such it represents a strategic effort to excite children about astronomy and provides them with a powerful tool to increase science literacy. The program was made possible by a generous gift from Jean and Ric Edelman to the American Astronomical Society (AAS). The AAS teamed with the National Optical Astronomy Observatory (NOAO); Galileoscope, LLC; the National Earth Science Teachers Association (NESTA); and the Astronomical Society of the Pacific (ASP) to distribute telescopes, mainly during teacher workshops. Through the professional development efforts of NESTA, ASP, and NOAO's Teaching With Telescopes program some 1,400 teachers received Galileoscopes and hands-on training on how to teach optics and astronomy with them. All participating teachers received Galileoscopes free of charge. Another 1,500 or so teachers not connected with these organizations also received telescopes free of charge through an Internet ordering system, paying only for shipping. Under this combination of programs more than 15,000 Galileoscopes have been given to active teachers, reaching an estimated 300,000 students. The professional development program uses a combination of face-to-face workshops, a train-the-trainer model, and Internet-based self-paced instruction. We describe the Edelman Galileoscope Education Program design, training materials, and distribution networks, as well as the geographic distribution of the teachers who received Galileoscopes. This program represents an efficient and effective model for quickly distributing valuable science teaching materials to urban, suburban, and rural teachers - including homeschoolers - across the United States.

248.04

Using Solar Filters with a Galileoscope

Erika Grundstrom¹, R. S. Taylor² ¹Vanderbilt University, ²SUNY-Oswego.

Exhibit Hall

One of the lasting legacies of the International Year of Astronomy in 2009 is the Galileoscope. People around the world have one, but there is a major astronomical object they aren't supposed to look at - the Sun! We found that in order to facilitate observations during the actual school day, one best incorporate the Sun. We report on a project to build and use solar filters for the Galileoscope and incorporate them into the standard daytime classroom.

We will describe the filters and a curriculum we are testing and discuss the difficulties we encountered (number one being this extended solar minimum).

We acknowledge a SEED grant from the Astronomical Society of the Pacific and that this work is supported in part by the Vanderbilt University Learning Sciences Institute (LSI) and the Institute of Educational Sciences (IES).

248.05 Stellar Spectroscopy: Barcodes to the Stars Angela R. Sarrazine¹

¹Fernbank Science Center.

Exhibit Hall

Peering at the night sky, and more specifically, at all the stars overhead, one begins to wonder: How do astronomers determine the composition of stars if they cannot travel to them and return samples to Earth for use in a laboratory? One way in which astronomers can make these determinations is by using the "starlight" itself. Spectroscopy is a powerful tool in astronomy. The analysis of stellar spectra can reveal the composition, temperature, and velocity of an object as well as several other pieces of information. In an effort to increase student understanding of how spectroscopy works, an analogy to barcodes has been employed with 9th grade students. Young students are very familiar with the scanning technology currently utilized at most stores. While not a one to one analogy of the process, students can begin to understand that the series of black and white lines, the width of the lines, and the spacing between assists the computer in identifying the item for purchase. By a similar token, an astronomer looks at the spectral lines of a star and based upon the thickness, separation, and location of the lines can begin to determine some of the properties of the celestial object.

248.06

A MOSAIC for the Science Classroom

Vincent L. Fish¹, M. M. Needles¹, A. E. E. Rogers¹, D. Costa², J. Cadigan³, C. Clements⁴, S. K. May⁵ ¹*MIT Haystack Observatory*, ²*Lynnfield High School*, ³*Oak Hill Middle School*, ⁴*Marlborough High School*, ⁵*Middlesex School*.

Exhibit Hall

MOSAIC (Mesospheric Ozone System for Atmospheric Investigations in the Classroom) is a project to engage secondary and undergraduate students in authentic inquiry-based science learning using a network of inexpensive spectrometers monitoring the mesospheric ozone concentration. The MOSAIC system observes the 11 GHz emission line of ozone using electronics built around satellite television equipment.

The possibilities for student investigation are broad and scientifically significant. MOSAIC observations have confirmed diurnal variations in mesospheric ozone concentration and detected semiannual variations that may be due to inter-hemispheric meridional circulation of water vapor. Possible future projects include monitoring the temperature of the mesosphere and correlations with the solar cycle. Students are also encouraged to design their own investigations with MOSAIC data. Early results have been reported in a major scientific journal, and further scientific progress is likely as future MOSAIC systems are deployed -- increasing the sensitivity and geographic coverage of the network. Complete teaching units, including slides, laboratory activities, background information, student worksheets, and conformance with national and Massachusetts educational standards, have been developed to integrate MOSAIC into a classroom environment. One unit introduces the layers of the atmosphere, Earth's energy balance, the greenhouse effect, processes of ozone creation and destruction, noctilucent clouds, heat transfer, the laws of thermodynamics, radio waves (including radio astronomy), and fluid behavior. A second unit, currently being tested in classrooms, uses the MOSAIC system to motivate and deepen understanding of a large portion of electromagnetism in a conceptual physics class. MOSAIC has also been used in a local high school chemistry class. MOSAIC is still in development and is funded by the National Science Foundation.

An Innovative Collaboration on Dark Skies Education

Constance E. Walker¹, M. Mayer², NOAO EPO Students

¹National Optical Astronomy Observatory, ²Cooper Center for Environmental Learning. Exhibit Hall

Dark night skies are being lost all over the globe, and hundreds of millions of dollars of energy are being wasted in the process. Improper lighting is the main cause of light pollution. Light pollution is a concern on many fronts, affecting safety, energy conservation, cost, human health, and wildlife. It also robs us of the beauty of viewing the night sky. In the U.S. alone, over half of the population cannot see the Milky Way from where they live.

To help address this, the National Optical Astronomy Observatory Education and Public Outreach (NOAO EPO) staff created two programs: Dark Skies Rangers and GLOBE at Night. Through the two programs, students learn about the importance of dark skies and experience activities that illustrate proper lighting, light pollution's effects on wildlife and how to measure the darkness of their skies. To disseminate the programs locally in an appropriate yet innovative venue, NOAO partnered with the Cooper Center for Environmental Learning in Tucson, Arizona. Operated by the largest school district in

Tucson and the University of Arizona College of Education, the Cooper Center educates thousands of students and educators each year about ecology, science, and the beauty and wonders of the Sonoran Desert.

During the first academic year (2009-2010), we achieved our goal of reaching nearly 20 teachers in 40 classrooms of 1000 students. We gave two 3-hour teacher-training sessions and provided nineteen 2.5-hour on-site evening sessions on dark skies activities for the students of the teachers trained. One outcome of the program was the contribution of ~1000 "GLOBE at Night 2010" night-sky brightness measurements by Tucson students. Training sessions at similar levels are continuing this year. The partnership, planning, lesson learned, and outcomes of NOAO's collaboration with the environmental center will be presented.

248.08

The James Webb Space Telescope RealWorld-InWorld Design Challenge: Involving Professionals in a Virtual Classroom

Margaret Masetti¹, S. Bowers²

¹ADNET Systems, Inc. & NASA GSFC, ²National Institute of Aerospace. Exhibit Hall

Students around the country are becoming experts on the James Webb Space Telescope by designing solutions to two of the design challenges presented by this complex mission. RealWorld-InWorld has two parts; the first (the Real World portion) has high-school students working face to face in their classroom as engineers and scientists.

The InWorld phase starts December 15, 2010 as interested teachers and their teams of high school students register to move their work into a 3D multi-user virtual world environment. At the start of this phase, college students from all over the country choose a registered team to lead InWorld. Each InWorld team is also assigned an engineer or scientist mentor. In this virtual world setting, each team refines their design solutions and creates a 3D model of the Webb telescope. InWorld teams will use 21st century tools to collaborate and build in the virtual world environment.

Each team will learn, not only from their own team members, but will have the opportunity to interact with James Webb Space Telescope researchers through the virtual world setting, which allows for synchronous interactions. Halfway through the challenge, design solutions will be critiqued and a mystery problem will be introduced for each team.

The top five teams will be invited to present their work during a synchronous Education Forum April 14,

2011. The top team will earn scholarships and technology.

This is an excellent opportunity for professionals in both astronomy and associated engineering disciplines to become involved with a unique educational program. Besides the chance to mentor a group of interested students, there are many opportunities to interact with the students as a guest, via chats and presentations.

248.09

Astronomy 101 in Washington State High Schools

Julie H. Lutz¹, S. Garner¹, T. Stetter¹, J. McKeever¹, V. Santo Pietro² ¹Univ. of Washington, ²Shoreline High School.

Exhibit Hall

The University of Washington in the High School (UWHS) program enables high schools to offer the 5 quarter credits Astronomy 101 (Astr 101) course for college credits. The credits are transferable to most colleges and universities. The course provides an alternative to advance placement courses and programs such as Washington's Running Start whereby high school students take courses at community colleges. Astr 101 focuses on stars, galaxies and the universe, as well as background topics such as gravitation, electromagnetic radiation and telescopes. The course satisfies the UW "natural world" and "quantitative/symbolic reasoning" distribution requirements. Students must pay a fee to enroll, but the credits cost less than half what they would cost for the course if taken on one of the UW campuses. The course can be offered as either one semester or full-year at the high school. Teachers who offer Astr 101 must be approved in advance by the UW Astronomy Department, and their syllabi and course materials approved also. Teachers receive orientation, professional development opportunities, classroom visits and support (special web site, answering questions, making arrangements for campus visits, planetarium visits) from astronomy department course coordinator. The UWHS Astr 101 program has produced positive outcomes for the astronomy department, the participating teachers and the students who complete the course. In this poster we will discuss our 5 years of experience with offering Astr 101, including benefits to the students, teachers, high schools, university and department, student outcomes, course assessments and resources for offering the course.

248.10

Educational Aspects of Searching for Variable Stars in the Mid-IR Sky

Margaret (Peggy) Piper¹, B. Thomas², R. DeCoster³, R. Rosignolo¹, J. Romero¹, J. Christensen¹, O. Rudio², D. Brennan², A. Antonow³, A. Sehgal³, D. Hoard⁴, S. Howell⁵

¹Lincoln-Way North High School, ²North Middle School, ³Niles West High School, ⁴Spitzer Science Center, ⁵NOAO.

Exhibit Hall

Using archival Spitzer Space Telescope Infrared Array Camera (IRAC) data, our team of students, educators and astronomers attempted to discover new variable stars in mid-infrared (3-8 micron) wavelengths. Our educational goal was to learn, and then disseminate, methods to ways to (a) utilize various image processing software tools and (b) subsequently analyze and display gathered data in a meaningful form in order to identify variable stars. We processed a total of 6447 images in three target fields, examining a total of 227 stars for this project. Photometric data were produced for each point source and that data was used to create light curves and brightness vs. standard deviation curves. Our target fields were taken from Spitzer observations of exoplanet transits, which utilized comparatively long, uninterrupted sequences of IRAC observations. This poster will illustrate how students and teachers learned to use imaging software to gather and display photometric data for targets in this project, and created tutorials to enhance the use of these tools in astronomy classrooms. This work was supported by the NASA's Spitzer Science Center and NOAO (National Optical Astronomy Observatory).

Authentic Astronomy Research Experiences for Teachers: the NASA/IPAC Teacher Archive Research Program (NITARP)

Luisa M. Rebull¹, V. Gorjian², G. Squires¹, NITARP Team

¹Caltech, ²JPL.

Exhibit Hall

How many times have you gotten a question from the general public, or read a news story, and concluded that "they just don't understand how real science works"? One really good way to get the word out about how science works is to have more people experience the process of scientific research. The way we have chosen to do this, since 2004, is to provide authentic research experiences for teachers using Spitzer data. (The program used to be called the Spitzer Teacher Program for Teachers and Students, and in 2009 was rechristened NITARP, the NASA/IPAC Teacher Archive Research Program.) We partner small groups of teachers with a mentor astronomer, they do research as a team, write up a poster, and present it at an AAS meeting. The teachers incorporate this experience into their classroom, and their experiences color their teaching for years to come, influencing 100s of students per teacher. Four different teams from the 2010 class of NITARP teachers are presenting scientific and educational results at this AAS meeting; please look for them!

248.12

Using NASA Archives in High Schools to Study AGN

Helen Petach¹, T. Spuck¹, K. Meredith¹, E. Ramseyer¹, V. Gorjian² ¹NASA-NITARP, ²JPL.

Exhibit Hall

The NITARP (NASA IPAC Teacher Archive Research Project) program provides a link between NASA researchers and high school teachers and students. This past year the Luminous Data Miners (LDM) developed and implemented a research plan to investigate whether the UV light emitted from the accretion disk of an Active Galactic Nucleus (AGN) is correlated with the IR emission from its surrounding dust. Contemporaneous data was obtained from the GALEX and Spitzer data archives for a set of galaxies. Scientists, teachers, and students from across the country work together in this authentic research experience. Students learned about the physics of the science in question, the structure of the archived data stored in NASA databases, extraction methods for obtaining relevant data, use of photometry tools to make brightness measurements, and relevant correlations that could be determined. Our results suggest that students are eager to have these research opportunities and will make use of data archives to carry out research projects to answer relevant questions. This poster will highlight the process the students and teachers went through and the tools they developed along the way.

248.13

Multi-Sensory Approach to Search for Young Stellar Objects in CG4

Vivian L. Hoette¹, L. M. Rebull², K. McCarron³, C. H. Johnson⁴, C. Gartner⁵, J. VanDerMolen⁵, L. Gamble⁶, L. Matche⁵, A. McCartney⁵, M. Doering⁶, R. Crump⁴, A. Laorr⁴, K. Mork⁴, E. Steinbergs⁴, E. Wigley⁴, S. Caruso⁴, N. Killingstad⁴, T. McCanna⁴

¹University of Chicago, Yerkes Observatory, ²SSC/IPAC/CalTech, ³Oak Park and River Forest High School, ⁴Breck School, ⁵Wisconsin School for the Deaf, ⁶Wisconsin Center for the Blind and Visually Impaired. Exhibit Hall

Individuals with disabilities - specifically individuals who are deaf or hard of hearing (DHH) and/or blind and visually-impaired (BVI) - have traditionally been underrepresented in the fields of Science, Technology, Engineering, and Math (STEM). The low incidence rate of these populations, coupled with

geographic isolation, creates limited opportunities for students to work with and receive mentoring by professionals who not only have specialty knowledge in disability areas but also work in STEM fields. Yerkes Observatory scientists, along with educators from the Wisconsin School for the Deaf, the Wisconsin Center for the Blind and Visually Impaired, Breck School, and Oak Park and River Forest High School, are engaged in active research with a Spitzer Science Center (SSC) scientist. Our ultimate goals are threefold; to engage DHH and BVI students with equal success as their sighted and hearing peers, to share our techniques to make astronomy more accessible to DHH and BVI youth, and to generate a lifelong interest which will lead our students to STEM careers. This poster tracks our work with an SSC scientist during the spring, summer, and fall of 2010. The group coauthored another AAS poster on finding Young Stellar Objects (YSO) in the CG4 Nebula in Puppis. During the project, the students, scientists and teachers developed a number of techniques for learning the necessary science as well as doing the required data acquisition and analysis. Collaborations were formed between students with disabilities and their non-disabled peers to create multi-media projects. Ultimately, the projects created for our work with NITARP will be disseminated through our professional connections in order to ignite a passion for astronomy in all students - with and without disabilities. This research was made possible through the NASA/IPAC Teacher Archive Research Project (NITARP) and was funded by NASA Astrophysics Data Program and Archive Outreach funds.

248.14

Building Astronomy Curriculum to Include the Sight Impaired: Week long summer camp activities for Middle School Students adherent to Washington State Curriculum Standards (EARL's)

Natalie Ramien¹, S. R. Loebman¹, V. Player², A. Larson¹, N. B. Torcolini³, A. Traverse¹ ¹University of Washington, ²Shanghai Community International School, China, ³Stanford. Exhibit Hall

Currently astronomy learning is heavily geared towards visual aids; however, roughly 10 million people in North America are sight impaired.

Every student should have access to meaningful astronomy curriculum; an understanding of astronomy is an expectation of national and state science learning requirements.

Over the last ten years, Noreen Grice has developed Braille and large print astronomy text books aimed at sight impaired learners.

We build upon Grice's written work and present here a five day lesson plan that integrates 2D reading with 3D activities.

Through this curriculum, students develop an intuitive understanding of astronomical distance, size, composition and lifetimes.

We present five distinct lesson modules that can be taught individually or in a sequential form: the planets, our sun, stars, stellar evolution and galaxies.

We have tested these modules on sight impaired students and report the results here.

Overall, we find the work presented here lends itself equally well to a week long science camp geared toward middle school sight impaired taught by astronomers or as supplemental material integrated into a regular classroom science curriculum. This work was made possible by a 2007 Simple Effective Education and Dissemination (SEED) Grant For Astronomy Researchers, Astronomical Society of the Pacific through funds provided by the Planck Mission, Jet Propulsion Laboratory, California Institute of Technology.

249 *Cosmology* Poster Session *Exhibit Hall*

249.01

Enhanced Absorption and Emission in Hydrogen Lines at the Epoch of Recombination D. Cassell¹, **Vladimir Strelnitski**²

¹Shippensburg University & Maria Mitchell Obs, ²Maria Mitchell Obs.. Exhibit Hall

The important problem of possible disturbances in the Comsic Microwave Background (CMB) left by high *n* hydrogen transitions during the epoch of recombination has been intensively studied in the past decade. However the simplifying assumptions made in most of the studies may be misleading. We consider the problem from the thermodynamic point of view to show that (1) the available detailed calculations of hydrogen level populations and ensuing non-equilibrium effects (such as masing) for the ordinary HII regions are not applicable to the recombining expanding Universe; (2) taking into account the collisional interaction of neutral atoms with electrons and ions in computer simulations is crucially important for quantitative predictions of possible spectral disturbances. It appears, in particular, that a proper account for collisions (and the treatment of all the angular momentum sublevels separately) will show the possibility of not only emission but also *absorption* disturbances left in the CMB by the epoch of recombination. Our approach allows us to estimate only roughly the wavelength domains where the emission and absorption disturbances are anticipated. Challenging computer simulations taking into account collisions and considering the *l*-substates separately up to the Rydberg levels with $n \sim 200$ are needed to make more accurate quantitative predictions. This project was supported by NSF/REU grant AST-0851892 and the Nantucket Maria Mitchell Association.

249.02

The Cosmic Infrared Background Experiment: Flight Characterization Of The Ciber Narrow Band Spectrometer.

Louis R. Levenson¹, J. Battle², J. J. Bock³, A. Cooray⁴, V. Hristov¹, B. Keating⁵, D. Lee⁶, P. Mason¹, T. Matsumoto⁷, S. Matsuura⁷, U. W. Nam⁶, T. Renbarger⁵, I. Sullivan¹, K. Suzuki⁸, T. Wada⁷, M. Zemcov¹ ¹Caltech, ²JPL, ³JPL, Caltech, ⁴University of California, Irvine, ⁵University of California, San Diego, ⁶KASI, Korea, Republic of, ⁷ISAS/JAXA, Japan, ⁸Nagoya University, Japan. Exhibit Hall

Subtraction of the Zodiacal light foreground is the dominant source of uncertainty in absolute photometric measurements of the extra-galactic background at near-infrared to optical wavelengths. The second flight of the Cosmic Infrared Background ExpeRiment (CIBER) occurred on July 10th, 2010. CIBER is a NASA sounding rocket experiment carrying four co-aligned instruments including two imaging telescopes with wide passbands centered at 1 and 1.6 microns, respectively, as well as a low resolution spectrometer and a narrow-band spectrometer. THE CIBER spectrometers are absolutely calibrated in collaboration with NIST. The narrow-band spectrometer filter is centered on the Ca II solar Fraunhofer line at 854.2 nm and is designed to measure the equivalent width of the solar line reflected by the interplanetary dust in order to obtain an absolute measurement of the Zodiacal contribution to the infrared sky at that wavelength. In conjunction with measured low resolution spectrum from 700 to 1900 nm, this will provide an accurate independent check of the DIRBE Zodiacal light models. Here we describe the NBS instrument, calibration and in-flight characterization.

Imaging the Spatial Fluctuations in Cosmic IR Background from Reionization with CIBER

Chris Frazer¹, J. Bock², A. Cooray¹, M. Kawada³, M. Kim⁴, D. Lee⁵, L. Levenson², T. Matsumoto⁴, S. Matsumuura³, K. Mitchell-Wynne¹, T. Renbarger⁶, J. Smidt¹, I. Sullivan², T. Arai³, K. Tsumura³, T. Wada³, M. Zemcov²

¹University of California, Irvine, ²Caltech, ³Institute of Space and Astronoutical Science (ISAS), Japan Aerospace Exploration Agency (JAXA), Japan, ⁴Seoul National University, Korea, Republic of, ⁵Korea Astronomy and Space Science Institute (KASI), Korea, Republic of, ⁶University of California, San Diego. Exhibit Hall

The Cosmic Infrared Background Experiment (CIBER) is a rocket-born absolute photometry imaging and spectroscopy experiment optimized to detect unresolved infrared signatures of first-light galaxies that were present during reionization. The signatures from reionization are theorized to be dominant at the wavelengths upon which CIBER surveys. CIBER consists of two wide field imagers to measure the extragalactic background fluctuations in the H and I-Bands (1.6 and 0.9 microns respectively) of the cosmic infrared background (CIB) as well as two spectrometers designed to take measurements of the foreground zodiacal light and the absolute Extragalactic Background Light (EBL) spectrum They imagers are capable of examining high-redshift (z ~ 10-20) CIB fluctuations which will facilitate in the study of surface densities of sources associated with reionization. Studies of galaxies with similar redshift parameters (z > 6) are largely unaccounted for. The spectrometer configuration consists of one low resolution spectrometer and one narrow band spectrometer. They are respectively designed to take measurements of the absolute Extragalactic Background Light (EBL) spectrum, and foreground zodiacal light. In this poster we present the specifications for both CIBER imagers and detail how the fluctuations from galaxies during reionization will be measured.

249.04

A Constraint On the Integrated Mass Power Spectrum Out to z = 1100 From Lensing of the Cosmic Microwave Background

Joseph Smidt¹, A. Cooray¹, A. Amblard¹, S. Joudaki¹, D. Munshi², M. G. Santos³, P. Serra¹ ¹UC Irvine, ²University of Edinburgh, United Kingdom, ³Instituto Superior Tecnico, Portugal. Exhibit Hall

The temperature fluctuations and polarization of the Cosmic Microwave Background (CMB) are now a well-known probe of the Universe at an infant age of 400,000 years. During the transit to us from the surface of last scattering, the CMB photons are expected to undergo modifications induced by the intervening large-scale structure. Among the expected secondary effects is the weak gravitational lensing of the CMB by the foreground dark matter distribution. We derive a quadratic estimator that uses the non-Gaussianities generated by the lensing effect at the four-point function level to extract the power spectrum of lensing potential fluctuations integrated out to z ~ 1100. Using WMAP 7-year temperature maps, we report the first direct constraints of this lensing potential power spectrum and find that it has an amplitude of $A_L = 0.96 \pm 0.60$, 1.06 ± 0.69 and 0.97 ± 0.47 using the W, V and W+V bands, respectively.

249.05

A Cosmological Discriminator Designed to Avoid Selection Bias

Amir Shahmoradi¹, R. J. Nemiroff¹

¹*Michigan Technological University.*

Exhibit Hall

We define a new cosmological discriminator -- a ``one-sided Amati relation" -- which is defined by only the bright/soft side of the E_{iso} versus E_{peak} (Amati) relation, since this does not suffer from significant

selection bias. An advantage of this approach is that changing a GRB redshift would only slide it along the one-sided Amati relation, making actual GRB redshifts less important than how GRB brightness and hardness change with cosmological distance. Therefore, it is the slope of this one-sided Amati relation that makes it a cosmological model discriminator. We investigate the limits of the power of this method to discern between cosmological models where dark energy changes with redshift.

249.06

The Small-scale Clustering Of Massive Galaxies At 0.2<z<0.4

John K. Parejko¹, T. Sunayama¹, N. Padmanabhan¹, A. Berlind², M. Blanton³, F. van den Bosch¹, L. A. N. da Costa⁴, E. Kazin³, C. McBride², W. Percival⁵, F. Prada⁶, R. Skibba⁷, J. Tinker³, D. Wake¹, D. Weinberg⁸, A. Wetzel¹, M. White⁹, I. Zehavi¹⁰, Z. Zheng¹

¹Yale University, ²Vanderbilt, ³NYU, ⁴Observatório Nacional/BPG, Brazil, ⁵University of Portsmouth, United Kingdom, ⁶Instituto de Astrofisica de Andalucia, Spain, ⁷University of Arizona, ⁸Ohio State, ⁹Berkeley, ¹⁰Case Western.

Exhibit Hall

We show first results on the small-scale clustering of massive galaxies from the early Baryon Oscillation Spectroscopic Survey (BOSS) observations for 0.2 < z < 0.4. We present the real and redshift space clustering and the associated halo-occupation distribution modeling of the clustering results. We discuss the implications of these results for the final cosmological and dark energy constraints from BOSS.

249.07

LasDamas: Accurate Determination of the Abundance of Galaxy Clusters

Cameron McBride¹, A. A. Berlind¹, R. Scoccimarro², M. Manera³, J. Tinker², M. Busha⁴, R. Wechsler⁵, H. Wu⁵, F. van den Bosch⁶

¹Vanderbilt University, ²New York University, ³University of Portsmouth, United Kingdom, ⁴University of Zurich, Switzerland, ⁵Stanford University, ⁶Yale University.

Exhibit Hall We study the abun

We study the abundance of clusters in the LasDamas suite of cosmological N-body simulations. These simulations contain an unprecedented volume (750 Gpc³/h³) and are seeded with initial conditions using second order lagrangian perturbation theory (2LPT) instead of the standard Zel'Dovich approximation (ZA). Recent results show that ZA leads to unphysical transients that predominantly inhibit the collapse of the earliest forming density peaks such as massive halos of galaxy clusters. We compare our results to simulations seeded with ZA, but using the same starting redshift, cosmology, simulation parameters, and phases. We find a significant systematic bias in the number density of clusters that grows with both halo mass and redshift. For masses greater than 2e14 Msun/h, we find that ZA underpredicts the abundance of halos by 3% at z=0 and 15% at z=1. For masses greater than 5e14 Msun/h, these rise to 5% and 20%, respectively. We show that this bias is only partially mitigated by using ZA with a higher starting redshift. We demonstrate the effect on cluster abundance persists regardless of halo defintion, quantifying the effect for both spherical overdensity and friends-of-friends halos. If unaccounted for, this bias can lead to inaccurate cosmological constraints on dark energy, or be misinterpreted as primordial non-Gaussianity.

The Structure Of Dark Matter Halos From The Lasdamas Project

Daniel Musher¹, A. A. Berlind¹, C. K. McBride¹, R. Scoccimarro², M. Manera², R. H. Wechsler³, M. Busha³, F. C. van den Bosch⁴

¹Vanderbilt University, ²New York University, ³Stanford University, ⁴Yale University. Exhibit Hall

We examine the density profiles of dark matter halos by analyzing data from the LasDamas (Large Suite of Dark Matter Simulations) project. LasDamas consists of a large suite of cosmological N-body simulations that follow the evolution of dark matter in the universe. The aim of LasDamas is to obtain adequate resolution in many large boxes, resulting in a huge volume appropriate for statistical studies of galaxies and halos. We measure density profiles for these halos, and fit NFW and other models to our measurements. With such a large dataset, we are able to study the full density profile distribution and its dependence on mass, redshift, and environment -- even in the regime of rare cluster-size halos. Finally, we investigate the sensitivity of our results to particle mass resolution, as well as choice of halo definition.

249.09

Cosmology from the HST Cluster Supernova Survey

Nao Suzuki¹, G. Aldering¹, R. Amanullah², K. Barbary³, L. Barrientos⁴, M. Brodwin⁵, N. Connolly⁶, K. Dawson⁷, S. Deustua⁸, A. Dey⁵, M. Doi⁹, M. Donahue¹⁰, P. Eisenhardt¹¹, E. Ellingson¹², L. Faccioli¹, V. Fadeyev¹³, H. Fakhouri³, A. Fruchter⁸, D. Gilbank¹⁴, M. Gladders¹⁵, G. Goldhaber¹, A. Gonzalez¹⁶, A. Goober², A. Gude¹⁷, J. Hennawi¹⁸, H. Hoekstra¹⁹, E. Hsiao¹, X. Huang¹, B. Jannuzi⁵, J. M. Jee²⁰, B. Koester¹⁵, M. Kowalski²¹, C. Lidman²², E. V. Linder³, L. Lubin²⁰, J. Meyers³, T. Morokuma⁹, S. Perlmutter¹, M. Postman⁸, J. Rhodes¹¹, P. Rosati²³, P. Ripoche¹, D. Rubin³, E. Rykoff¹, D. J. Schlegel¹, A. L. Spadafora¹, S. A. Stanford²⁰, D. Stern¹¹, N. Yasuda²⁴, Supernova Cosmology Project

¹Lawrence Berkeley National Lab., ²Stockholm University, Sweden, ³University of California, Berkeley, ⁴Universidat Catolica de Chile, Chile, ⁵National Optical Astronomy Observatories, ⁶Hamilton College, ⁷University of Utah, ⁸Space Telescope Science Institute, ⁹University of Tokyo, Japan, ¹⁰Michigan State University, ¹¹Jet Propulsion Laboratory, ¹²University of Colorado, ¹³University of California, Santa Cruz, ¹⁴University of Waterloo, Canada, ¹⁵University of Chicago, ¹⁶University of Florida, ¹⁷University of Minnesota, ¹⁸Max Planck Institute for Astronomy, Germany, ¹⁹Leiden Observatory, Netherlands, ²⁰University of California, Davis, ²¹University of Bonn, Germany, ²²Australian Astronomical Observatory, Australia, ²³European Southern Observatory, Germany, ²⁴Institute for the Physics and Mathematics of the Universe, Japan.

Exhibit Hall

We report the results from the HST Cluster Supernova Survey (PI: Perlmutter; see Dawson et al. AJ, 2009). This survey introduced a novel approach to efficiently discover SNe Ia at very high redshift while controlling for host galaxy environment and dust extinction. By monitoring 25 high redshift massive clusters with the Advanced Camera for Surveys (ACS), a total of 20 SNe Ia were discovered, including nine SNe in z > 0.9 galaxy clusters and eight z > 0.9 SNe Ia in the field, nearly doubling the existing high redshift SNIa sample. (For a discussion of the rates, see K. Barbary, dissertation talk at this meeting). We propagate statistical and systematic errors from supernova measurements (see Rubin et al. poster presentation) to the combined cosmological analysis with CMB and BAO observations. Recent observations show that supernova properties may depend on the host galaxy environment. Galaxy clusters provide us with very well constrained host galaxy environments and are well-suited for testing host galaxy effects on the SNe Ia properties. We present such studies and the best cosmological parameter measurements from this survey. This work has been supported by the Office of Science, U.S.

Department of Energy, through contract DE-AC02-05CH11231 and in part by NASA through grants associated with HST-GO-10496.

249.10

The Next Union Compilation of Type Ia Supernovae

David Rubin¹, G. Aldering², R. Amanullah³, K. Barbary¹, N. Connolly⁴, K. Dawson⁵, M. Doi⁶, V. Fadeyev⁷, H. Fakhouri¹, A. Fruchter⁸, G. Goldhaber², A. Goobar³, E. Hsiao², X. Huang¹, Y. Ihara⁶, A. Kim², M. Kowalski⁹, C. Lidman¹⁰, E. Linder², J. Meyers¹, T. Morokuma¹¹, S. Perlmutter¹, P. Ripoche², E. Rykoff², A. Spadafora², N. Suzuki², N. Takanashi¹¹, N. Yasuda⁶, Supernova Cosmology Project

¹UC Berkeley, ²Lawrence Berkeley National Laboratory, ³Stockholm University, Sweden, ⁴Hamilton College, ⁵University of Utah, ⁶University of Tokyo, Japan, ⁷UC Santa Cruz, ⁸Space Telescope Science Institute, ⁹Humboldt Univerity, Germany, ¹⁰Australian Astronomical Observatory, Australia, ¹¹National Astronomical Observatory of Japan, Japan.

Exhibit Hall

In a series of papers (Kowalski (ApJ, 2008), Amanullah (ApJ, 2010)) we have developed techniques to combine multiple datasets, search for tensions between datasets, quantify systematic errors, and to propagate this understanding into the cosmology fits. Here, we present refinements to our analysis, and the addition of new supernovae. We also discuss applications for future ambitious surveys. This work has been supported by the Office of Science, U.S. Department of Energy, through contract DE-AC02-05CH11231 and in part by NASA through grants associated with HST-GO-10496.

249.11

Our Magnetic Universe: The Nature of High Polarization Prompt Gamma Ray Bursts and the Origin of Dark Energy

Howard D. Greyber¹

¹San Jose.

Exhibit Hall

The author's "Strong" Magnetic Field model (SMF), created in 1961, is an approach identical to that urged for study by Zel'dovich in 1983. SMF is described in my 2005 paper, published in the CD of the Proceedings of the 22nd Texas Relativistic Astrophysics Symposium (also existing in Astro-ph0509223). A first order phase transition called the Spinodal Decomposition Instability causes a rapid exponential growth of the fluctuations at Combination Time. One of several important results from SMF is the very early generation, soon after Combination Time, of an intense, relativistic stable "storage current loop" in most active galaxies and quasars that was formed by gravitational collapse of the huge pre-galactic plasma cloud in the presence of the primordial magnetic field. This suggests that gamma ray bursts (GRB) are created, similar to what happens on Earth at an accelerator, by a beam on target (BOT) process. A dense target, like a white dwarf, neutron star, planet, et al, crossing the beam, causes the optical transient or "fireball" that is observed at the site of a gamma ray burst (GRB). The extremely powerful "storage current ring", or loop current, heats the target into a plasma blob. The plasma blob is accelerated, exits the current ring, passing through the enormous ordered magnetic field around the current loop, thus inducing the polarization that has been observed. An Appendix explains the Origin of Dark Energy according to the SMF model, which, uniquely, derives the Origin of Magnetic Fields occurring at Combination Time, (NOT far later when galaxies form, as believed by most astrophysicists for over eight decades), and also uses a comment by Albert Einstein. That result produces the unique Supercluster Topology where almost all the mass is on a shell surrounding an extremely high vacuum, explaining the current Accelerating Expansion observed in our universe.

249.12 The Search for Neutrino Oscillations Daniel Gershun¹

¹University of Hartford. Exhibit Hall

Neutrinos offer insight into such fundamental questions as the dominance of matter over antimatter, the dynamics of supernovae, and the large scale structure of the universe. NOvA (NUMI Off-axis Neutrino Oscillations) is an experiment that will measure crucial neutrino properties using a Near Detector at Fermilab, where the neutrinos are generated in the NuMI beam, and a large Far Detector in Ash River, MN, 735 km from Fermilab. The main objective of this experiment is the measurement of the parameters associated with the oscillation of muon to electron neutrinos.

Indiana University with funding from the NSF and DOE are responsible for building and testing the water-cooled heat sinks required for the thermal and environmental control of the Avalanche Photodiodes used in the light detection generated in the Liquid Scintillator. The heat sinks have a brass body with a TEC chip that cools the APD to -15 C. The water system that conducts the 5 W generated by the thermal control has been designed to withstand a maximum pressure of 100 psi. Several of the construction techniques and QC tests performed will be described.

249.13

Kukaniloko: A Living Legend

Kamira Barron¹

¹University of Calgary, Canada.

Exhibit Hall

This poster investigates a sacred site (heiau) named Kukaniloko on the Hawaiian Island of Oahu. This heiau has been important to the Hawaiians for a number of reasons; it was an ancient astronomical observatory, a navigation school and was the birthplace of a number of prominent kings. Kukaniloko is often mentioned in Hawaiian mythology and ethnohistorical records. Traditionally, it is a place of astronomical, navigational, political, social, educational and ritual importance. Constructed in the 11th century A.D., it has birthing stones, springs, astronomical orientations, and a stone (pohaku) canoe, which is a navigational compass stone. There are contemporary Hawaiians who continue to use this site, and solstices and equinoxes are observed to this day. The guardian/caretaker (kahu) of the site encourages the native community to spend time at Kukaniloko, and those with expertise to help revive the ancient knowledge. Two years ago, he conducted a ceremony of initiation for a new priest (kahuna) during the Autumnal equinox at this heiau. In 1797, King Kamehameha I attempted to have his son born at the site, but his wife's illness prevented her from getting there. Hawaiians interpreted this as the gods' disapproval of his having committed human sacrifices. The name Kukaniloko can be revealing. The word ku means to stand fast, stop, anchor, also to appear, show, beginning. Kani means sound or noise of any kind, and to strike. Loko means inside, within, disposition, heart, and feelings. The name indicates that this was and still is a place of great importance in Hawaiian culture.
250 *Interstellar Medium, Dust* Poster Session *Exhibit Hall*

250.01

The Dusty Pleiades: ERE And PAH Emission, What Do They Have In Common? Uma P. Vijh $^{\rm 1}$

¹University of Toledo.

Exhibit Hall

The Pleaides and the surrounding regions exhibits many interesting dust grain emissions and interactions. We report new optical observations (2 deg x 3 deg) of the nebula in 12 narrow band BATC filters. These data clearly show the presence of heretofore undetected extended red emission (ERE). This data combined with archival Spitzer data shows the rich and complex distribution of the various grain populations in the ISM in the region. We explore the possible relations between the optical ERE and mid-IR emission from PAHs.

250.02

A Study of Interstellar Medium Components of the Ohio State University Bright Spiral Galaxy Survey Melissa Butner¹, S. E. Deustua², A. Conti², J. Smtih³

¹Austin Peay State University & STScI, ²STScI, ³Austin Peay State University. Exhibit Hall

Multi-wavelength data can be used to provide information on the interstellar medium of galaxies, as well as on their stellar populations. We use the Ohio State University Bright Spiral Galaxy Survey (OSBSGS) to investigate the distribution and properties of the interstellar medium in a set of nearby galaxies. The OSBSGS consists of B, V, R, J, H and K band images for a over 200 nearby spiral galaxies. These data allow us to probe the dust temperatures and distribution using color maps. When combined with a pixel based analysis, it may be possible to tease out, perhaps better constraining, the heating mechanism for the ISM, as well as constrain dust models. In this paper we will discuss our progress in understanding, in particular, the properties of dust in nearby galaxies.

Melissa Butner was a participant in the STScI Summer Student Program supported by the STScI Director's Discretionary Research Fund. MB also acknowledges support and computer cluster access via NSF grant 07-22890.

250.03

Dust Emission in M33 (HERM33ES)

Mederic Boquien¹

¹University of Massachusetts.

Exhibit Hall

Dust emission is one of the main windows on the physics of galaxies and on star formation as the radiation from young, hot stars is absorbed by the dust

and reemitted at longer wavelengths. The recently launched Herschel now provides a view of dust emission in the

far-infrared at an unequaled resolution and quality up to 500 μ m. In the context of the Herschel HERM33ES open time key project, we are studying the

moderately inclined, local group galaxy M33 located 840 kpc away. In this article, combining Spitzer and Herschel data ranging from 3.6 μ m to 500 μ m,

along with HI and H α maps, we have studied the emission of the dust at the high resolution of 150 pc. Combining Spitzer and Herschel bands, we have

provided new estimators of the TIR and SFR. The study of the colors of the warm and cold dust temperatures shows that the temperature of the former is dictated by young, massive stars at high SFR but it is taken over by the old population at lower SFR. Conversely, the temperature of the warm dust seems to be tightly driven by the evolved stellar population.

250.04

Using M Dwarfs to Map Extinction in the Local Galaxy

David Jones¹, A. A. West¹, J. Foster¹

¹Boston University.

Exhibit Hall

We use spectra of more than 56,000 M dwarfs from the Sloan Digital Sky Survey (SDSS) to create a highlatitude extinction map of the local Galaxy. Our technique compares spectra from low-extinction lines of sight as determined by Schlegel, Finkbeiner, & Davis to other SDSS spectra in order to derive improved distances and accurate extinctions for the stars in the SDSS data release 7 M dwarf sample. Unlike most previous studies, which have used a two-color method to determine extinction, we fit extinction curves to fluxes across the entire spectral range from 5700 to 9200 angstroms for every star in our sample. Our result is an extinction map that extends from a few tens of pc to approximately 2 kpc from the Sun. We also use a similar technique to create a map of R_v values within approximately 1 kpc of the Sun and find that they are roughly consistent with the widely accepted diffuse interstellar medium value of 3.1. Using our extinction data, we derive a dust scale height for the local galaxy of 176 ± 15 parsecs.

250.05

Polarizations, Magnetic Fields, and Dust towards 26 Outer Galaxy Open Clusters

April Pinnick¹, D. P. Clemens¹, M. Pavel¹

¹Boston University.

Exhibit Hall

We present near-infrared H band (1.6 micron) wide field imaging polarimetry towards 26 open star clusters. All polarizations are from Mimir on the 1.8m Perkins Telescope outside Flagstaff, Arizona. These clusters in the 2nd and 3rd galactic quadrants sample a broad range in reddening (E(B-V) \sim 0.0 - 0.9), distance (0.85 - 5.5 kpc), and age (log(t) \sim 7.0 - 9.7). The polarizations of the member stars provide strong implications for dust grain and magnetic field properties along these lines of sight. This work partially supported by NSF grant AST 09-07790

250.06

Uncertainty in the Ratio of Total-to-Selective Extinction as a Function of Background Star Spectral Type

Kristen A. Larson¹

¹Western Washington Univ.

Exhibit Hall

The value of the ratio of total-to-selective extinction, R_V , allows extinction to be calculated from observation of reddening. Variation in the ratio due to variation in the foreground grain size distribution adds additional uncertainty to knowledge of extinction and ultimately distance. This work uses model calculations to show that when R_V is measured by comparing observed colors of background stars to their intrinsic colors based on spectral type, the uncertainty in R_V is a complicated function of spectral type. How sensitive the value of R_V is to the precision of the spectral type varies widely across the range of stellar spectral type. Results from this modeling can be used to select stars that would yield the most accurate map of real variations in the value of R_V .

2175 Å Dust Map of the Milky Way

Erik A. Hoversten¹, D. E. Vanden Berk², C. Gronwall¹, M. H. Siegel¹ ¹*Pennsylvania State University*, ²*St. Vincent College.*

Exhibit Hall

The mean extinction curve of the Milky Way dust exhibits a pronounced bump at 2175 Å which is weaker in the LMC and absent in the SMC. Studies along individual lines of sight show significant variation in the strength of the bump within the Milky Way as well. We present a map of 2175 Å strength variation in the north galactic cap. The map is created using SDSS photometry and spectroscopy of stars to estimate their UV colors. These predicted model colors are compared to observed GALEX UV colors to infer the strength of the 2175 Å bump. We acknowledge funding from the NASA GALEX GI program.

250.08

The Milky Way Tomography with SDSS

Michael Berry¹, Ž. lvezić²

¹*Rutgers University,* ²*University of Washington.*

Exhibit Hall

We use SDSS photometry for 73 million stars to simultaneously obtain best-fit main-sequence stellar energy distribution and the amount of dust extinction along the line of sight towards each star. Using a subsample of 23 million stars with 2MASS photometry, whose addition enables more robust results, we show that SDSS photometry alone is sufficient to break degeneracies between intrinsic stellar color, dust amount, and dust properties. These fits enable detailed studies of the dust properties and its spatial distribution, and of the stellar spatial distribution at low galactic latitudes (|b| < 30 degrees). Our results are in good agreement with the extinction normalization given by the Schlegel, Finkbeiner & Davis (1998, SFD) dust maps at high northern galactic latitudes, but indicate that the SFD extinction map appears to be consistently overestimated by about 20% in the southern sky. For the latter, we find a ratio of the total to selective absorption to be $R_v = 3.01 \pm 0.05$ (random)±0.1 (systematic) over most of the high-latitude sky. At low galactic latitudes (|b| < 5 degrees), we demonstrate that the SFD map cannot be reliably used to correct for extinction because most stars are embedded in dust, rather than behind it, as is the case at high galactic latitudes. We present evidence that sometimes the SFD map grossly overestimates the dust extinction at low galactic latitudes even when these distance effects are accounted for. In cases where such discrepancies are large, they seem correlated with the distribution of molecular gas. We analyze three-dimensional maps of the best-fit R_v and show that it can reach values as high as 5-6 in some low-latitude regions with large amounts of dust.

250.09

IMAGER: Expected Results from UV Dust Observations of M101

Meredith E. Danowski¹, T. A. Cook¹, K. D. Gordon², S. Chakrabarti¹ ¹Boston University, ²Space Telescope Science Institute.

Exhibit Hall

The Interstellar Medium Absorption Gradient Experiment Rocket (IMAGER) will probe the correlation between ultraviolet dust extinction, and the metallicity and radiation environment in M101. With four 400Å-wide bandpasses, IMAGER targets UV extinction features and will utilize M101 as a laboratory for studying dust in HII regions. M101 is nearly face-on, has large angular extent, a steep metallicity gradient, and contains many well-studied HII regions. Evidence from studies of starburst galaxies indicates that active, high mass star formation modifies the UV dust extinction curve, demonstrated by the lack of a characteristic 2175Å bump. With ultraviolet photometry from IMAGER, we will measure the apparent strength of the 2175Å bump, the far-UV rise, and the UV continuum. With this data, infrared data from Spitzer, the DIRTY radiative transfer model, and stellar evolution models, we will examine changes seen in the UV extinction curve and IR emission features as a function of metallicity and radiation field hardness. This study will directly impact our understanding of the nature of dust and our ability to accurately account for the effects of dust on observations at all redshifts.

250.10

Characterizing Intergalactic Dust with X-ray Halos

Lia Corrales¹, F. Paerels¹

¹Columbia University.

Exhibit Hall

By estimating the total mass of metals produced through star formation versus the amount of metals locked up in galaxies and intergalactic gas, researchers have concluded that about half of the metals in the intergalactic medium are locked up in dust grains, with Omega ~ 10^{-5} (Aguirre 1999). Large dust grains are more likely to survive the processes, such as wind and radiation pressure, that enrich the intergalactic medium. Thus intergalactic dust is likely to be gray, leaving no trace of optical reddening that is typical of interstellar dust. We explore the possibility of detecting large (~1 micron) intergalactic dust grains through small angle X-ray scattering. A bright X-ray point source, when imaged, will appear surrounded by a halo 10-100 arcseconds wide. The scattering cross section for X-rays increases with the grain radius to the fourth power. For a power law distribution of grain sizes, the optical depth of the universe to soft X-ray scattering reaches 20% for sources out to z=2. We present models of X-ray halos with various grain size distributions and explore the limits a dust-suffused universe places on current and future X-ray missions, the determination of cosmological parameters, and intergalactic enrichment models.

250.11

Understanding S Stars by C/O Ratios and s-Process Element Abundances

David J. Arrant¹, A. Speck¹

¹University of Missouri.

Exhibit Hall

The chemical evolution of dust expelled from Asymptotic Giant Branch (AGB) stars is influenced by the Carbon to Oxygen (C/O) ratio, because of the high stability of Carbon Monoxide (CO). S Stars are thought to be "in between" Carbon-rich AGB stars and Oxygen-rich AGB stars, having a C/O ratio of near unity and thus are expected to have interesting dust properties. However, there is not a precise definition for S Stars. S Stars are currently defined by the molecular bands in their spectra; they have reasonably strong zirconium oxide (ZrO) bands, which are believed to be indicative of dredge-up of s-process nucleosynthesis products. However, production and dredge-up of s-process elements may not scale with the production and dredge up of s-process elements such as Zirconium (Zr), especially when we consider destruction of carbon through hot bottom burning. If we are to understand the effect of chemistry, either in terms of s-process enhancements or C/O ratios, we must be able to characterize our sample stars and thus a more precise definition of S Stars is needed.

Preliminary studies are presented to understand the properties of S Stars by determining what relationships exist between C/O ratios and s-process elements abundances.

The Effect Of Chemical Abundances On Dust Formation: Stellar Nucleosynthesis Vs. Metallicity. Angela Speck¹, S. Chan¹

¹Univ. of Missouri.

Exhibit Hall

The most important factors influencing the mineralogy of dust forming in circumstellar outflows are density, temperature and chemical composition of the outflowing gas. We have tested the hypothesis that small variations in C/O ratio can explain subtle changes in the mineralogy of circumstellar dust by studying a sample of O-rich AGB stars of known C/O. We show that while C/O has little to no effect on the IR spectral features, the abundance of iron-group elements has a significant effect.

Our results imply that the details of chemical enrichment of the universe, rather than simply increasing ``metal" abundances, play a significant role in determining what sort of dust should form when and where. This has implications for dust formation at high redshift.

250.13

Through The Looking Glass: Laboratory Studies Of Calcium Bearing Amorphous Pyroxenes Jordan D. Wheeler¹

¹University of Missouri - Columbia.

Exhibit Hall

Many astrophysical environments exhibit spectral features around 10µm and 18µm that have long been attributed to amorphous (glassy) silicates. However existing laboratory spectral data for amorphous silicates do not cover a wide enough compositional range to allow astronomers to interpret their observations without large uncertainty. In particular, while magnesium-rich silicates have been studied extensively, the effect of some other likely components (e.g. calcium, aluminium) have been largely neglected, even though these elements are expected to play a major role in dust condensation. We present laboratory spectra for a series of 8 glasses, produced by quenching silicate melts of calciumbearing pyroxene composition. The samples range from the Mg end-member (enstatite; MgSiO3) to the Ca end-member (wollastonite; CaSiO3). The halfway composition corresponds to the mineral diopside (CaMgSi2O6), which has previously been proposed to explain observed spectral features. CaMgSi2O6 glass has a much broader $\sim 10 \mu m$ peak than Mg2Si2O6 glass, due to the more varied bonding environments resulting from two different network modifying cations, and its peak extends to longer wavelengths, consistent with the greater mass of Ca. The presence of other elements is likewise expected to result in broader features and subtle changes in peak position. In addition to a systematic study of the effect of Ca substitution for Mg, we present some more complex glasses that include Na, Al and Fe as minor constituents. In addition we present measurements of the viscosity of these glasses to determine the glass transition temperature (Tg), which provides an important constraint on the thermal history of observed glassy silicate.

250.14

Studying the Effect of C/O Ratio on Dust around Carbon Star

Harrison Knoll¹, A. Speck¹

¹University of Missouri -Columbia.

Exhibit Hall

In order to study the effect of chemistry on the formation of dust around carbon-rich AGB stars, we have selected a sample of C-rich stars of known C/O ratio. Using radiative transfer (RT) modeling we determine the parameters of the dust shells of 8 carbon stars. In particular we focus on modeling the 11 micron SiC feature, and the overall shape of the spectral energy distribution (SED) while keeping other parameters (i.e. grain size distribution, relative shell thickness and dust density distribution) constant.

This is done to ameliorate the problem of degeneracy within model parameters. In order to determine whether the relative abundances of SiC and carbon are related to the C/O ratio, we sought correlations between various physical, stellar and spectral parameters including effective stellar temperature, C/O ratio, modeled SiC abundance, pulsation period etc. We present our RT models and discuss the correlations between parameters or lack thereof.

250.15

Effects of Temperature and Composition on Spectral Features of the Olivine minerals.

Suklima Guha Niyogi¹, A. Speck¹, C. Dijkstra¹

¹University of Missouri.

Exhibit Hall

Crystalline olivine minerals (Mg2xFe(2-2x)SiO4 ; x=[0,1]) has been detected in many astronomical environments. The Infrared Space Observatory (ISO), Spitzer Space Telescope, Herschel Space Telescope detected several sharp near and far infrared (IR) spectral features around young stars, comets and evolved stars, which have been attributed to crystalline silicates (mostly as forsterite, Mg2SiO4, the Mg-rich end member of the olivine series). Laboratory measurements of the different mineral spectral features are compared to astronomical observations in order to match and identify the dust species present in circumstellar envelopes. However, the positions, widths and amplitudes of the spectral features are strongly influenced by the temperature and composition of the dust grains. Consequently there is degeneracy such that a given spectral feature may have more than one explanation. We present these competing effects for crystalline olivine minerals and investigate how the spectral features change in position, shape and strength with varying Mg/[Mg+Fe] ratio and with temperature and develop a scheme for mapping the degeneracy space. Our goal is to determine to what extent this degeneracy can be broken observationally in order to improve our understanding of astronineralogy around the evolved stars.

250.16

Identity Crisis: True Composition of Circumstellar Dust Questioned

Lucas Miller¹, A. Speck¹, S. Guha Niyogi¹

¹University of Missouri.

Exhibit Hall

Cosmic dust plays an important role in many astrophysical environments. A major source of cosmic dust is dying stars. Intermediate mass stars (0.8-8 solar masses) eventually evolve to become Asymptotic Giant Branch (AGB) stars which produce vast quantities of dust. During the AGB phase, the star expands and contracts releasing shells of gas that drift away from the star and eventually cool to condense dust. Using spectral observations from the Infrared Space Observatory (ISO), we have investigated the farinfrared spectral dust features (in the 15-40 micron range) from a large sample of AGB star spectra. Previously, it has been thought that these circumstellar dust shells are dominated by amorphous (glassy) silicates and that crystalline grains are rare. Furthermore, on those rare occasions that crystalline silicates occur, they are expected (and usually observed) to be Mg-rich. Using laboratory spectra of crystalline olivines and pyroxenes with a range of Mg/Fe, we show that the majority of the observed astronomical spectra are matched surprisingly well with crystalline silicates, especially with high iron content. This discovery contradicts the previously accepted dust composition. Fe-rich crystalline silicate dust compositions are inconsistent with current dust formation hypothesis and dust condensation sequences, and thus our research calls the current accepted wisdom into question.

251 *Interstellar Medium, Molecular Clouds, HII Regions* Poster Session *Exhibit Hall*

251.01

Hydromagnetic Signal Speeds In Weakly Ionized, Dusty Interstellar Clouds Having A Spectrum Of Grain Radii

Glenn E. Ciolek¹, W. G. Roberge¹ ¹New York Center for Astrobiology and Department of Physics, Applied Physics, and Astronomy Rensselaer Polytechnic Inst.. Exhibit Hall

We study the propagation of magnetohydrodynamic waves traveling perpendicular to the direction of the magnetic field in weakly ionized, dusty molecular clouds and cores, for the physically relevant situation in which there is a continuous distribution of grain sizes. The effect of collisions of charged species with the predominantly neutral gas is accounted for in our system of governing equations. Also included is the interaction of charged grains with electron-shielded ion quasiparticles, which aids attachment of grains to magnetic field lines for frequencies less than the grain-quasiparticle hybrid frequency. The dispersion relation for dusty clouds is analyzed and we present the results for models having grain distribution functions that are consistent with interstellar extinction observations (Mathis et al 1977; Weingartner & Draine 2001). Magnetosound waves and plasma diffusion modes dependent on the inertia of the grains are identified and their behavior as a function of frequency is described. Our results indicate that when there is a spectrum of grain sizes the dust population consists of two distinct dynamical sub-groups: grains that are small enough to be actually coupled to the magnetic field (Hall parameter > 1), referred to as "MHD active" grains, and larger grains that are decoupled from the field by collisions with neutral gas particles (Hall parameter < 1), which can be called "MHD inactive" grains. The limiting MHD signal speed for the lowest-frequency, farthest-traveling waves is set by the net mass of the "MHD active" grains that are loaded onto magnetic field lines, which can be a substantial portion (~ 30% - 70%) of the total dust mass. As a result, the limiting MHD signal speed in dusty clouds is significantly smaller than what it would be in dust-free clouds. This can have important consequences for the formation of MHD precursors and shocks in clouds and cores.

251.02

Magnetic Fields in Photodissociation Regions

Benjamin Montet¹, D. S. Balser², D. A. Roshi², J. Shitanishi³, T. M. Bania⁴, R. T. Rood⁵ ¹University of Illinois, ²National Radio Astronomy Observatory, ³University of Southern California, ⁴Boston University, ⁵University of Virginia.

Exhibit Hall

Photodissociation regions (PDRs) are predominately neutral volumes at the molecular cloud/HII region interface of star forming complexes. Far-ultraviolet photons with energies below 13.6 eV can escape HII regions and dissociate atoms with a lower ionization potential, such as carbon, within PDRs. This has been verified, for example, by detection of carbon radio recombination line (CRL) emission from PDRs. Roshi (2007) suggested that the non-thermal component of CRL line width is dominated by magnetic turbulence. He combined data from observations of several CRLs separated in frequency and radiative transfer models of the CRL emission regions to derive the magnetic field strength. Here, we discuss PDR models toward four HII regions using observations from the Green Bank Telescope (GBT) and compare the derived magnetic field strength with published Zeeman observations to test this hypothesis.

Analysis of MHD Interstellar Turbulence using Tsallis Statistics

Benjamin M. Tofflemire¹, A. Lazarian², B. Burkhart²

¹University of Washington, ²University of Wisconsin.

Exhibit Hall

In an effort to characterize interstellar magneto-hydrodynamic (MHD) turbulence, we study probability distribution functions (PDFs) of spacial increments of density, velocity, and magnetic field strength for fourteen three dimensional ideal isothermal MHD simulations. We fit the PDFs using the Tsallis function and study the fit parameters dependence on the compressibility and magnetization of the gas. For three dimensional density, column density, and PPV (Position-Positions-Velocity) data we find that the Tsallis function fits PDFs of high resolution MHD turbulence well, with the fit parameters corresponding to amplitude and width showing strong sensitivities to the sonic and Alfvén Mach numbers. Specifically, the width of the PDF is sensitive to magnetization especially in cases where the sonic number is high. These dependencies are also found for cases where smoothing, noise, and cloud-like boundary conditions are introduced to simulate observable qualities. This could make Tsallis statistics a useful tool in characterizing magnetic fields in the interstellar medium.

This work was supported by the National Science Foundation's REU program through NSF Award AST-1004881.

251.03

Driven Hydromagnetic Waves and Shocks in Dusty Interstellar Clouds

Maximilian Katz¹, G. E. Ciolek¹, W. G. Roberge¹

¹New York Center for Astrobiology

and Department of Physics, Applied Physics, and Astronomy

Rensselaer Polytechnic Institute.

Exhibit Hall

Dust grains are an important component of star-forming molecular clouds. Grains play a fundamental role in interstellar chemistry, and as a consequence of this, they may contribute to reactions of astrobiological interest. Under typical conditions, most dust grains are electrically charged, and will be a source of electrical current, in addition to gas-phase ions and electrons. Depending on their size, the gas density, and the field strength, charged dust grains can couple to the magnetic field and become loaded onto the field lines threading a cloud. As a result of this coupling, grains can significantly alter magnetohydrodynamic (MHD) phenomena in star-forming regions.

Using linear algebra and Fourier transform methods, we have created a numerical code that calculates the time-dependent evolution of MHD disturbances that propagate perpendicular to the direction of the magnetic field within weakly ionized, dusty interstellar clouds and cores. We apply this code to a model of colliding clouds to study the formation and early-time evolution of hydromagnetic waves and shocks. The results of models with grains that are either poorly coupled or strongly coupled to the magnetic field are described and contrasted. We find that in clouds with strong coupling, the inertia added by grain loading on magnetic field lines dramatically reduces the rate at which a MHD signal --- the forerunner to a magnetic precursor --- propagates ahead of the shock, compared to that which occurs in models with poorly coupled grains.

251.03 Constraining Galactic Dynamo Models with NIR Polarimetry

Michael D. Pavel¹, D. P. Clemens¹, A. F. Pinnick¹

¹Boston University.

Exhibit Hall

Polarization of background starlight is used to probe interstellar magnetic fields. While it has been widely used at optical wavelengths, the near-infrared polarimetric sky remains largely unexplored. In addition to probing longer sightlines, NIR polarimetry is less affected by foreground magnetic structures which allows us to study the large-scale, quiescent Galactic magnetic field. We combine observed NIR polarimetry with simulated observations to constrain dynamo models of the Galactic magnetic field. Polarimetric data were obtained with the Mimir instrument on the Perkins Telescope along a line of constant Galactic longitude (I=150) with pointings spaced between -75<b<10. Magnetic field models and dust distributions were taken from the literature and used with a Stokes radiative transfer model to generate simulated observations at the same sky positions. No combination of dust and magnetic models adequately reproduces the polarimetric observations. Further, comparison of the data with the model-driven simulations significantly rejects all tested A0 type magnetic field models. This work is supported by NSF grant AST-09-07790.

251.04

GPIPS Pathfinder for Three Dimensional Magnetic Fields

Julie May Moreau¹, D. P. Clemens¹, A. F. Pinnick¹, M. D. Pavel¹ ¹Boston University.

Exhibit Hall

The purpose of the Galactic Plane Infrared Polarization Survey (GPIPS) is to gain a better understanding of the nature of the magnetic field of our Milky Way. The survey works under the assumption that dust grains align with the Galactic magnetic field and polarize background starlight. GPIPS Pathfinder carries a single 10'x10' GPIPS zone (GP3195) through the entire science analysis process. This reveals what can be learned about the three dimensional structure of the magnetic field in this one zone, as well as guiding later analysis of the full GPIPS data set. H-band polarimetry was obtained using the Mimir instrument on the Perkins 1.83m telescope outside Flagstaff, Arizona. We also used Mimir to obtain medium resolution (R=560-780) H- and K-band spectroscopy of the 23 brightest stars in GP3195. These spectra have been classified using cross-correlation with spectral template grids. Distances to these stars were estimated via spectroscopic parallax. Combining these stellar distances with polarimetry, we seek to resolve the three dimensional magnetic field structure sampled by the GP3195 zone. This research was partially supported by the Boston University Undergraduate Research Opportunities Program (UROP) and AST 09-07790.

251.04

Ionized Gas in the Magellanic Bridge: A First Look at New Observations with WHAM

K. A. Barger¹, L. M. Haffner¹

¹University of Wisconsin-Madison.

Exhibit Hall

We present a first look at new spectroscopic H α observations towards the Magellanic Bridge. This is the first part of an ongoing study to investigate warm ionized gas within the Bridge in extensive detail using the Wisconsin H-alpha Mapper observatory. When completed, these H α observations will map the extent and large-scale velocity structure of the ionized gas, giving clues on the source(s) of ionization, the ionization fraction, and the mass of the ionized component. Future work will include extensively mapping the Bridge in H α , [S II], and [N II] as well as deep, targeted pointings in optical lines to gain

additional information on the electron temperature, metallicity, and sources of the ionization. This study will substantially advance our knowledge of the ionized component of the Bridge and will provide new insights on how this system is evolving and interacting with the Magellanic Clouds. This WHAM research is funded through NSF award AST-0607512.

251.05

Diffuse Ionized Gas in the Magellanic System: Early Results from WHAM-South

L. Matthew Haffner¹, G. J. Madsen²

¹Univ. of Wisconsin, Madison, ²Sydney Institute for Astronomy, School of Physics, University of Sydney, Australia.

Exhibit Hall

From its new vantage point at CTIO, the Wisconsin H α Mapper is poised to explore the full distribution and kinematics of diffuse plasma in extended gaseous structures near the Magellanic Clouds. Shaped by the interaction between the Clouds and the Milky Way, the Bridge, Stream, and Leading Arm gas complexes have been studied extensively in 21 cm emission and optical/UV absorption. With spectral resolution of 12 km/s, WHAM is able to separate optical emission from these structures and brighter local gas near v_{LSR} ~ 0 km/s. Combined with its unprecedented sensitivity to the limit of atmospheric line confusion (~ 10s of mR), we are embarking on a survey of the ionized component of the Magellanic System with WHAM. With observations of the southern component of our all-sky survey nearly completed, we have begun to examine some emission features toward the Magellanic System. Here we present a sample of several regions observed recently with WHAM in H α . WHAM was built and continues to operate with ongoing support from NSF. The research presented here is currently funded by award AST-0607512 and an International Program Development Fund from the University of Sydney.

251.06

MHD Simulations of a Supernova-driven ISM and the Warm Ionized Medium

Alex S. Hill¹, M. R. Joung², R. A. Benjamin³, L. M. Haffner¹, C. Klingenberg⁴, M. M. Mac Low⁵, K. Waagan⁶, K. A. Wood⁷

¹Univ. of Wisconsin-Madison, ²Columbia University, ³Univ. of Wisconsin-Whitewater, ⁴Würzburg University, Germany, ⁵American Museum of Natural History, ⁶University of Maryland, ⁷University of St. Andrews, United Kingdom.

Exhibit Hall

We present new 3D MHD simulations of a supernova-driven, stratified interstellar medium. We have previously shown that the density distribution arising from hydrodynamical versions of these simulations creates low-density pathways through which Lyman continuum photons can travel to heights |z| > 1 kpc. This naturally produces the warm ionized medium through photoionization due primarily to O stars near the plane. However, the hydrodynamical models reproduce the peak but not the width of the emission measure distribution observed in Wisconsin H-Alpha Mapper (WHAM) data. Here, we discuss the role of magnetic fields in the structure of gas away from the plane. We compare emission measure distributions from models with varying magnetic field strengths to the WHAM observations.

The simulations were performed using the adaptive mesh refinement grid code FLASH with the new MHD solver developed by Waagan et al.

This work was partly supported by NASA/SAO grant TM0-11008X and by NSF grant AST-0607512.

The Wisconsin H-Alpha Mapper Sky Survey: A First Look at the Global Distribution of Diffuse Ionized Gas in the Milky Way

Nitish Chopra¹, L. M. Haffner¹, R. J. Reynolds¹, G. J. Madsen², A. S. Hill¹, K. A. Barger¹, K. P. Jaehnig¹, E. J. Mierkiewicz¹, J. W. Percival¹, N. M. Pingel¹, D. T. Reese¹, M. C. Gostisha³

¹University of Wisconsin-Madison, ²Sydney Institute for Astronomy, School of Physics, University of Sydney, Australia, ³University of Wisconsin-Whitewater.

Exhibit Hall

After a year of observations from its new location on Cerro Tololo, the Wisconsin H α Mapper (WHAM) has nearly completed survey observations below $\delta < -30^{\circ}$. This new data combined with the Northern Sky Survey provides the first kinematic, all-sky survey of diffuse H α from the Milky Way. Aside from many large-scale, locally-ionized regions, much of this emission arises from the Warm Ionized Medium (WIM), a diffuse but thick component of the ISM that extends several kiloparsecs into the Galactic halo. WHAM was designed primarily to study the WIM, delivering a spatially integrated spectrum from a one-degree beam on the sky covering 200 km s⁻¹ with 12 km s⁻¹ spectral resolution. The short exposures of the survey reach sensitivity levels of about 0.1 R (EM ~ 0.2 pc cm⁻⁶) and reveal emission toward nearly every direction in the sky. Here, we present our early efforts at reducing this new southern dataset and offer a first look at the global distribution and kinematics of diffuse ionized gas throughout the Galaxy. WHAM and the research presented here are funded by NSF award AST-0607512. We also thank the excellent and responsive staff at CTIO in Chile for helping to keep our remote installation fully operational.

251.08

WHAM Discovery of a New Superbubble in Circinus

Martin Gostisha¹, R. A. Benjamin¹, L. M. Haffner²

¹UW-Whitewater, ²UW-Madison.

Exhibit Hall

We present a Wisconsin H-alpha Mapper (WHAM) survey of the fourth quadrant of the Galactic plane in diffuse emission from [S II] 6716 A, covering Galactic longitude I=270-360 degrees and latitude |b|<12 degrees. One of the more prominent features seen is a large-scale ionized bubble, centered at I=320.0 deg, b=3.4 deg with a diameter of 7 degrees. Spectra of the center of this region shows line splitting characteristic of an expanding bubble. A search for high mass star in the region shows that this bubble subtends over 40 O stars, including the cluster Pismis 20 which is part of the Circinus OB association. Assuming that the bubble is at the distance of this cluster, yields a bubble diameter of 300 parsec. When this is combined with the measured expansion velocity of 7 km/s, we derive a bubble age of approximately 2 Myrs, consistent with the estimated age of the Circinus OB association. We discuss the energetics of the bubble as well as the result of searching for this bubble using tracers at other wavelengths. This research was supported the NSF REU site grant to the University of Wisconsin-Madison.

251.09

Studying the Temperature and Ionization State of the Warm Ionized Medium

Melissa Halford¹, E. J. Mierkiewicz², R. J. Reynolds², G. J. Madsen³, L. M. Haffner², K. A. Barger², F. L. Roesler²

¹Cornell University, ²University of Wisconsin-Madison, ³University of Sydney, Australia. Exhibit Hall

Using data from the Wisconsin Hydrogen Alpha Mapper (WHAM) and Pine Bluff Observatory's Spatial Heterodyne Spectrometer (SHS), we studied the warm ionized component of the Galaxy's interstellar

medium (WIM). Line ratios of H-alpha, [N II], [O II] and [S II] emission were used to study the WIM gas in both the local spiral arm and more distant areas of the Galaxy. The strength of the [S II] line was used to measure the ionization state in a set of nine look directions and ratios of [N II]/H-alpha and [O II]/Halpha provide a measure of temperature. Our study expands upon and confirms the results of previous [O II] studies of the WIM, which limited themselves to line ratios including only the local component of the [O II] emission. The work presented here includes a detailed component analysis of WIM emission from non-local gas in the kinematically distinct Perseus spiral arm and uses [S II] data that was not available in the previous [O II] study. This work was supported by the National Science Foundation's REU program through NSF Award AST-1004881. WHAM is funded by the National Science Foundation through grant AST-0607512; the [OII] SHS is funded by the National Science Foundation through grant AST-0908894.

251.10

Probing Our Heliospheric History: Constructing A Density Profile Of The LISM In The Sun's Rearview Mirror.

Katherine Wyman¹, S. Redfield¹

¹Wesleyan University.

Exhibit Hall

In the course of our motion through the Galaxy, the Solar System has encountered many interstellar environments of varying characteristics. ISM density variations spanning six orders of magnitude are commonly seen throughout the general Galactic environment, and a sufficiently dense cloud within this range has the potential to compress the heliosphere to within one Astronomical Unit. We present a reconstruction of the density profile for the clouds we have most recently passed through based on high-resolution optical spectra towards nearby stars. The data were obtained with the Harlan J Smith 2.7-meter telescope coudé spectrograph at McDonald Observatory. Observations were made of interstellar NaI and Call doublet absorption towards 49 bright stars along the historical path of solar motion in our orbit around the center of the Galaxy. Spectra were taken of stars out to a distance of 480 parsecs, with a median separation distance of 5 parsecs between adjacent stars. No absorption is seen out to a distance of 120 pc (consistent with the Local Bubble), but a complex collection of absorbers (up to 10 components) is seen in stars between 130 and 480 pc. A possible link between our local interstellar environment, cosmic rays, and our planetary climate has long been a subject of interest to members of the astronomical community. Compression of the heliosphere (one of our three cosmic ray shields) due to passage through a dense interstellar cloud could have drastic effects on Earth's climate: global cooling (atmospheric dust deposition), weather patterns (cloud nucleation), and evolution (DNA mutations). A timescale of interaction with each ISM component in this path can be constructed and ultimately compared with Earth's geologic record.

251.11

Analysis Of Ultra Compact Ionized Hydrogen Regions Within The Northern Half Of The Galactic Disk John Bruce¹

¹Manchester College.

Exhibit Hall

From a catalog of 199 candidate ultra compact (UC) HII regions 123 sources included in the the intersection of the GLIMPSE (8 μ m),Cornish (6 cm), and Bolocam (~1.1 mm) galactic plane surveys (BGPS) were analyzed. The sources were sorted based on 6 cm morphology and coincidence with 8 μ m bubbles. The ~1.1 mm flux attributes were measured and calculations were performed to determine the ionized hydrogen contributions to the ~1.1 mm flux. The category averages and frequencies were obtained as well. Significant differences in HII percentages were present among the morphology groups

but ranged widely, without apparent distinction, between the bubble forming and triggered source categories.

251.12

Ha Survey of Emission Line Regions in M33 and Local Group Dwarf Galaxies

Cindy Blaha¹, T. Johnson¹, R. Cawthon¹, M. Dixon¹, C. Murray¹, P. Massey², P. Hodge³ ¹Carleton College, ²Lowell Observatory, ³University of Washington. Exhibit Hall

We present the results of a survey of H α emission line regions in M33 and seven dwarf galaxies in the Local Group (NGC6822, IC10, WLM, Sextans A and B, Phoenix and Pegasus). Using data from the Local Group Galaxy Survey (LGGS - see Massey et al, 2006)), we used continuum-subtracted H α emission line images to define emission regions with a faint flux limit of 10 -17 ergs-sec-1-cm-2 above the background. We have obtained photometric measurements for over 4000 H α emission regions in M33 and five of the seven dwarf galaxies. Using these regions, with boundaries defined by their H α -emission, we also determined fluxes for the continuum-subtracted [OIII] and [SII] images and constructed a catalog of H α fluxes, region sizes and [OIII]/ H α and [SII]/ H α line ratios. The HII region luminosity functions and size distributions for spiral galaxy M33 are compared with those of the dwarf galaxies NGC 6822 and IC10. For M33, the average [SII]/ H α line ratios, plotted as a function of galactocentric radius, display a linear trend with a very shallow slope. The galaxy-wide averages of [SII]/ H α line ratios correlate with the masses of the dwarf galaxies following the previously established dwarf galaxy mass-metallicity relationship. An interactive catalog of these LGGS emission line surveys will be made available on-line.

251.13

Wind Bubbles around Massive Stars: Ionization-Gasdynamics Modelling and X-ray Emission Calculations

Vikram Dwarkadas¹, D. Rosenberg²

¹Univ. of Chicago, ²National Center for Atmospheric Research.

Exhibit Hall

Using a code that employs a self-consistent method for computing the effects of photo-ionization on circumstellar gas dynamics, we model the formation of wind-driven nebulae around massive stars. Our algorithm incorporates a simplified model of the photo-ionization source, computes the fractional ionization of hydrogen due to the photo-ionizing flux and recombination, and determines self-consistently the energy balance due to ionization, photo-heating and radiative cooling. We take into account changes in stellar properties and mass-loss over the star's evolution. Our multi-dimensional simulations clearly reveal the presence of strong ionization front instabilities, similar to those seen in galactic ionization fronts. In this poster we describe the code, and show how inclusion of photo-ionization affects the wind bubble structure and dynamics. Using various X-ray emission models, we compute the X-ray flux and spectra from our wind bubble models, and compare to observed data. VVD's research is supported by grant TM9-0001X provided by NASA through the Chandra X-ray Observatory Center, which is operated by the Smithsonian Astrophysical Observatory for and on behalf of the National Aeronautics Space Administration under contract NAS8-03060.

251.14

More Samples of Massive Star Forming Complexes in the Spitzer GLIMPSE Survey

Eve J. Lee¹, N. Murray¹, M. Rahman¹

¹University of Toronto, Canada.

Exhibit Hall

In previous work, we identified 40 star-forming complexes (SFCs) in the 13 most luminous WMAP freefree sources, using Spitzer GLIMPSE and Midcourse Space Experiment surveys. The bubbles were interpreted as an evidence of radial expansion due to a central massive star cluster. The high free-free luminosity and negligible synchroton radiation demonstrated that the initial driver of the bubbles were not supernovae. Meanwhile, the energy injected into the interstellar medium by the bubbles was found to be similar to that required to maintain turbulent motion in the gas disk inside 8 kpc. In this work we report the identification of approximately 200 new SFCs in the 83 WMAP free-free sources using a combination of bubble morphology in 8 micron emission, radio recombination, and molecular line radial velocities. We also recover approximately 80% of the previously found 40 SFCs. We determine the expansion velocity, physical distance, and radius for all the complexes. We report their expansion kinetic energy and its relation to turbulent motion in the interstellar medium.

251.15

The Milky Way Project: Citizen Science with GLIMPSE

Robert Simpson¹, Milky Way Project Team

¹Oxford University, United Kingdom.

Exhibit Hall

The infrared Spitzer GLIMPSE Survey mapped the midplane of the Milky Way in exquisite detail (Benjamin et al., 2003; Churchwell et al. 2009). Features such as bubbles (HII regions, supernova remnants - Churchwell et al. 2006; 2007) and extended green objects (EGOs - Cyganowski et al. 2008) were extracted from these data through visual classification by a handful of researchers. The Zooniverse (Galaxy Zoo, Moon Zoo - http://www.zooniverse.org) aims to use GLIMPSE/MIPSGAL data, in conjunction with new GLIMPSE 360 data (Whitney et al. 2009), produce definitive maps of such structures through a new citizen science website.

A set of online tools have been developed that allow the public to draw the locations and sizes of such objects onto the GLIMPSE/MIPSGAL data. 'The Milky Way Project' will utilize the Zooniverse user base of over 320,000 volunteers to produce detailed catalogues of bubbles, and intermediate-mass young stellar objects (YSOs) in the GLIMPSE/MIPSGAL data. It will also aim to locate EGOs, identified by their bright 4.5 micron emission (Cyganowski et al. 2008). The science team will then perform a variety of follow-up work based on these catalogues.

Additionally we will ask users to identify interesting or unusual objects that they spot within the GLIMPSE/MIPSGAL images. These catalogues of objects, which will include star clusters (e.g. Mercer et al., 2005), stellar bowshocks (e.g. Povich et al. 2008; Kobulnicky, Gilbert and Kiminki 2010) and galaxies in the zone of avoidance (e.g. Marleau et al., 2009) can then be used to guide future research. 'The Milky Way Project' is the ninth citizen science project from the Zooniverse. As more data become available (e.g. from Herschel's HiGAL survey), the project aims to expand and look at other, more diverse features in far-infrared and submillimetre data.

251.16

Stereo 3-D Presentation of Hubble Space Telescope Imagery

Zoltan G. Levay¹, G. Bacon¹, H. E. Bond¹, T. M. Borders¹, C. A. Christian¹, L. M. Frattare¹, F. Hamilton¹, W. Januszewski¹, M. Livio¹, M. Mutchler¹, K. S. Noll¹, F. Summers¹

¹STScl.

Exhibit Hall

3-dimensional (3-D) visualizations are a means of adding depth to otherwise 2-dimensional images. For astronomical images, depth is frequently not measured, but relative depth relationships can be inferred. We present a 3-D visualization of a portion of the Carina Nebula imaged with the *Hubble Space Telescope*.

The source image is a color composite of two datasets obtained with the Advanced Camera for Surveys. Images in the $H\alpha$ +[N II] filter (F658N) were taken from a 2005 Carina Nebula survey mosaic by Smith et

al. (2010, MNRAS, 405, 1153). Images in the [O III] filter (F502N) were obtained by our team in 2010 in parallel to WFC3 observations of the nearby HH 901 region (*HST* proposal 12050).

A 3-D model was constructed from the color composite image by separating it into several planes. Stars and nebular structures were extracted from the image and placed on different planes in 3-D digital modeling software using morphology of nebular features to infer relative depth. Relief texture was added to some of the nebular structures in the model to further enhance the perception of depth. For a static image, frames rendered from the 3-D model at two different viewpoints are composited into a single image in anaglyph (red-blue) stereo that will be shown.

251.17

FUV Images and Physical Properties of the Orion-Eridanus Superbubble Region Young-soo Jo¹, K. Min¹, K. Seon²

¹*Korea Advanced Institute of Science and Technology (KAIST), Korea, Republic of,* ²*Korea Astronomy and Space Science Institute (KASI), Korea, Republic of.*

Exhibit Hall

The far-ultraviolet (FUV) C IV and H₂ emission spectra of Orion-Eridanus Superbubble (OES) is hereby presented. The OES seems to consist of multiple phase through the detection of highly-ionized gas and pervasive neutral hydrogen. The former is traced by hot gas while the latter is traced by cold medium. A spectral image made with H₂ fluorescent emission shows that the spatial distribution of hydrogen molecule is well correlated with the dust map. The model spectra was taken from a photodissociation region (PDR) radiation code which finds a best suitable parameter such as hydrogen density and intensity of the radiation field. C IV emission is caused by intermediate temperature ISM about 10⁵K. Therefore we could get more clear evidence to reveal the morphology of OES. In this process, the hydrogen density and gas temperature were also estimated. The data were obtained with the Far-Ultraviolet Imaging Spectrograph (FIMS) and the whole data handling were followed by previous FIMS analysis.

251.18

Simulating Dusty Wind-Blown Bubbles

Jessamy Rogers¹, C. Watson¹

¹Manchester College.

Exhibit Hall

24 micron and 70 micron band images of two wind blown bubbles-- N-90 and S-146-- were analyzed and used to constrain the results of a simulation using Cloudy 3D. In particular, the effects of the dust grains in the interior of the bubble were examined, including the impact of distance-variable grain size distributions. It was discovered that the emissions of N-90 were well reproduced by the simulation, although S-146 saw only moderate reproduction. In both cases, the best fit was produced by parameters of questionable realism.

251.19

Modeling the Evolution of Cold Cloud Interstellar Dust-Grain Ices

Tyler Pauly¹, R. T. Garrod²

¹Iowa State University, ²Department of Astronomy, Cornell University. Exhibit Hall

We investigate the formation and evolution of interstellar dust-grain ices under cold cloud conditions, with a particular emphasis on CO2. We use a three-phase model (gas/surface/mantle) to simulate the coupled gas--grain chemistry, allowing the distinction of the chemically-active surface from the ice layers preserved in the mantle beneath. We undertake to treat more accurately the quantum-tunneling rates of barrier-mediated surface reactions, and we explicitly consider competition between such reaction

rates and thermal hopping processes. These models show excellent agreement with the observed behavior of CO and CO2 ice in the interstellar medium. The observed threshold between regimes in which CO2 or CO is the dominant ice constituent after H2O is found to be caused ultimately by the near-complete gas-phase conversion of atomic carbon to CO, which is itself determined by CO and H2 self-shielding. The change in the availability of gas-phase carbon alters the balance of the grain-surface chemistry, leading to a sharp change-over in the dominance of CO2/CO. The most probable grain-surface production mechanism for CO2 is the formation of a loosely-bound O...CO complex, whose oxygen atom is easily hydrogenated, leaving a highly excited complex which quickly overcomes an activation energy barrier to form CO2 + H.

251.20

Cosmic Origins Spectrograph Observations Of A Dense Translucent Cloud

Theodore P. Snow¹, E. B. Burgh¹, J. P. Destree¹

¹Univ. of Colorado. Exhibit Hall

Cosmic Origins Spectrograph Observations of a Dense Translucent Cloud

Theodore P. Snow Eric B. Burgh

Joshua P. Destree

The *Cosmic Origins Spectrograph* (*COS*) has greater sensitivity at moderate resolution than any UV spectrograph before 2009. One of the *COS* programs is to obtain UV spectra of interstellar translucent clouds. In these clouds H₂ is expected to dominate over H I and carbon should be making the transition from C II to C I to CO. Now we have obtained spectra of NGC 2024 No. 1, the most reddened star in our program. This sightline conforms to the definition of an extreme translucent cloud, with H₂ far dominating over H I by two orders of magnitude while CO contains most of the carbon. This would be classified as dark cloud but for the fact that UV radiation passes through it - with difficulty. We present column densities of H I, H₂ (inferred from the good correlation with CH), and CO. We have also obtained *COS* spectra of a few other stars, notably Cyg OB 8A and HD 204287, and we compare them with NCG 2024 No. 1. Forthcoming observations will establish abundances of other neutral atoms, ionized species, and simple molecules.

251.21

On the Excitation of "Quasi-thermal" Lines of Methanol

Adam Michael¹, M. Baubock², V. Strelnitski³

¹Wesleyan U. & Maria Mitchell Obs., ²Boston U. & Maria Mitchell Obs., ³Maria Mitchell Obs.. Exhibit Hall

We revisit the problem of the excitation of "quasi-thermal" lines of methanol in dense molecular clouds. Our analysis is based on the observations of 13 clouds in the four rotational lines of *E*-methanol ($J_0 - J_{-1}$; J = 1-4) at 157 GHz using the 12-m ARO telescope on Kitt Peak (AZ) and on comparison of the results with the steady-state solutions for the level populations in a Monte-Carlo simulation of radiative transfer. A higher spectral resolution allowed us to deconvolve the blended 1_0 - 1_{-1} , 2_0 - 2_{-1} and 3_0 - 3_{-1} lines better than in previous works. Treating the 157 GHz lines as spontaneous and optically thin, we estimate the relative populations of the J = 1 to 4 levels in the K= 0 stack. Most of the sources demonstrate strong deviations from the thermal population distribution with a single excitation temperature. A number of them can be divided into two groups showing the signatures of either "Class I" or "Class II" pumping. This dichotomy is probably determined by the distance of the bulk of the observed gas from the closest IR source controlling the strength of the "Class II" pumping. However, a considerable number of sources do not fit into either class, some of them showing, in particular, a significant overheating of the 4_0 - 3_0 transition not predicted by either pumping model. This discrepancy can be due to oversimplification of our theoretical model. This project was supported by NSF/REU grant AST-0851892 and the Nantucket Maria Mitchell Association.

251.22

Grain Alignment in Starless Cores

Terry Jay Jones¹, M. Krejny¹, B. Andersson², P. Bastien³

¹Univ. of Minnesota, ²SOFIA Science Center, USRA, ³Univ. of Montreal, Canada.

Exhibit Hall

We present observations of the polarization at 2.2 microns of background field stars shining through dense molecular cloud cores with no ongoing star formation, so-called 'starless cores'. This allows us to extend the work of Whittet et al. to Av > 40 mag. We compare these results to previous polarimetry of background field stars and embedded YSO's. We find that beyond Av ~ 12 mag., the observations are consistent with the absence of polarizing grains at these extreme optical depths. This is in contrast for lines of sight to embedded YSO's, which maintain increasing polarization with optical depth up to Av = 100 mag.

251.23

Spatially Resolved H₂ Line Ratios in the HH7 Bow Shock

Rosemary E. Pike¹, T. R. Geballe¹, A. C. Chrysostomou², M. G. Burton³, P. W. J. L. Brand⁴ ¹Gemini Observatory, ²Joint Astronomy Center, ³University of New South Wales, Australia, ⁴Royal Observatory, United Kingdom.

Exhibit Hall

We have obtained K-band spectra, at R~5,000 and 0.3 arc-second angular resolution, of the HH7 bow shock, using the Near-infrared Integral Field Spectrograph (NIFS) at Gemini North. The spectra include H2 lines covering a wide range of upper state energy levels, from ~6,000 K to ~25,000 K. We have measured the strengths of the rovibrational H2 lines 1-0 S(0) through S(2) and Q(1) through Q(4); 2-1 S(0) through S(3); 3-2 S(0) through S(3); and 4-3 S(3) and S(4). The H2 line intensity ratios will be used to determine the excitation temperature at different positions in the bow shock. Continuous shock (Cshock) models with ionized gas and magnetic mediation tend to predict that the temperature is constant through much of a shocked gas column and thus that the excitation temperature at each position will be independent of which line ratios are used to calculate it, but will vary with location in the bow shock. In the jump shock (J-shock) scenario, in which the gas is heated very suddenly and begins to cool immediately, the excitation temperature varies through the post-shock gas and line ratios depend on the line pair chosen. In this case one would expect to observe the same variation in excitation at all locations. Previous observations of shocks in a number of molecular clouds seem to support the J-shock behavior, but this may be a product of insufficient angular resolution, with previous observations unable to resolve separate shock fronts. Our angular resolution over the 3 x 3 arc-second field of view positioned along the bow shock of HH7 is an improvement by a factor of five over previous observations.

251.24

Monte-carlo Simulation For Dust Scattering In The Ophiuchus Molecular Complex

Lim Tae-Ho¹, K. Min¹, K. Seon²

¹KAIST, Korea, Republic of, ²KASI, Korea, Republic of.

Exhibit Hall

We present the results of FUV dust scattering simulation, which is based on the Monte-Carlo method. In this simulation, we focus on the multiple scattering in the Ophiuchus complex region because the single scattering case in the region already reported by Lee et al. 2008.

We compare the simulation result to the FUV intensity with FIMS and the single scattering result. We also discuss the parameters related to the results of this simulation, such as asymmetry factor, albedo and other different setting-ups.

251.25

Investigating the Density Structure of Bok Globule CB188

Andrew Johnson¹, A. C. Updike¹, D. H. Hartmann¹

¹Clemson.

Exhibit Hall

Extinction effects are ubiquitous in the interstellar medium of galaxies. In particular, extinction due to molecular clouds can significantly change the color and brightness of background or embedded objects. The structure of molecular clouds is an important observable, relevant for the initial conditions under which star formation takes place. Mapping the effects of extinction across a molecular cloud can be used to deduce its internal structure. We present such an analysis for Bok Globule CB188 which we observed with the 0.9m SARA telescope at Kitt Peak National Observatory. The geometry of CB188 is such that it can be approximated by a spherical model. We investigate several possible density structures (such as constant density and the Bonnor-Ebert model) and compare them to our observations of a changing apparent radius as a function of wavelength.

This project was funded by the National Science Foundation Research Experiences for Undergraduates (REU) program through grant NSF AST-1004872.

251.26

The CO Isotope Ratio of the Large Magellanic Cloud

Sarah Wyss¹, J. Ott¹, D. Meier², T. Wong³, A. Hughes⁴, J. Pineda⁵, E. Muller⁶ ¹National Radio Astronomy Observatory, ²New Mexico Institute of Mining and Technology, ³University of Illinois, ⁴Swinburne University of Technology, Australia, ⁵Jet Propulsion Laboratory, ⁶Nagoya University, Japan.

Exhibit Hall

Giant molecular clouds (GMCs) are the home of star formation, yet are difficult to observe and thus their physical characteristics remain largely unknown. The proximity, size, inclination and star-forming properties of the Large Magellanic Cloud (LMC, distance 50kpc) present a perfect opportunity for a comprehensive, high-spectral-resolution and high-spatial-resolution survey of these clouds. Using the ¹²CO (1-0) and ¹³CO (1-0) Magellanic Mopra Assessment (MAGMA) data, we study over 155 giant molecular clouds distributed throughout the LMC at 8pc resolution. The ¹³CO (1-0) transition is detected at or above the level of significance in all clouds examined. The intensity ratio of the ¹³CO (1-0) to ¹²CO (1-0) to ¹²CO (1-0) transition be highly uniform across the LMC, not varying strongly with GMC evolutionary state, galactocentric regions, star formation rate or interaction with the Milky Way. We discover an unexplained correlation between ¹²CO (1-0) and ¹³CO (1-0) and examine the galaxy-wide ¹³CO (1-0) to ¹²CO (1-0) ratio, simulating observations of similar, more distant galaxies. Comparison of this ratio with the ratio measured locally from individual clouds yields an overall ¹³CO (1-0) filling factor of 0.3 of ¹²CO(1-0).

Infrared Study of Star Forming Regions in the Magellanic Clouds via Spitzer

Brandon L. Lawton¹, K. D. Gordon¹, SAGE-LMC Spitzer Legacy Team, SAGE-SMC Spitzer Legacy Team ¹STScl.

Exhibit Hall

The study of the infrared properties of star forming regions allows us to probe the nature of the UV obscuring dust and the central ionizing stellar populations. The close proximity of the Magellanic Clouds allows us to probe the nature of these star forming regions at small spatial scales. We present the photometry and results of the first infrared-selected star forming region catalogs of the LMC and SMC using the Spitzer Space Telescope and compare the results to H-alpha selected catalogs in the literature. The sources are selected in 24um via a clump-finding algorithm. An analysis of star forming region infrared spectral energy distributions, luminosity functions, size distributions, and computed star formation rates are explored, with differences between the LMC and SMC highlighted.

251.28

Detection Of New High Velocity Clouds Using The Leiden-Argentina-Bonn Hi All-sky Survey

Tyler Engel¹, B. Wakker², C. Witt¹, M. C. Gostisha¹, E. Thomson¹, L. Stratman¹, R. A. Benjamin¹ ¹University of Wisconsin-Whitewater, ²University of Wisconsin-Madison.

Exhibit Hall

We describe a new effort to use the Leiden/Argentina/Bonn (LAB) Galactic HI survey to update the highvelocity clouds catalog of Wakker and van Woerden (1991). The LAB survey (Kalberla et al 2005) combined the Leiden-Dwingeloo survey (Hartmann and Burton 1997) with a complementary southern sky survey (Arnal et al 2000). This survey provides improved angular spacing (0.5 deg vs. 1 deg) and velocity resolution (1 km/s vs. 16 km/s), although it was less sensitive than previous surveys. We describe how we fit the LAB high velocity gas with Gaussian components, providing three levels of review for the quality of fits, and compare the resulting high velocity cloud catalog to previous results for galactic latitudes greater than b=45 degrees. This research was supported by NASA ATP grant NNX10AI70G to the University of Wisconsin-Whitewater.

251.29

Forbidden Velocity Wings In The Inner-Galaxy ALFA Low-latitude HI (I-GALFA) Survey

Ji-hyun Kang¹, B. Koo², S. J. Gibson³, K. A. Douglas⁴, G. Park², J. E. G. Peek⁵, E. J. Korpela⁶, C. E. Heiles⁶ ¹NAIC/Arecibo Observatory, ²Seoul National University, Korea, Republic of, ³Western Kentucky University, ⁴University of Exeter, United Kingdom, ⁵Colombia University, ⁶University of California - Berkeley. Exhibit Hall

The faint wing-like features at velocities beyond the velocity boundaries of the Galactic rotation (Forbidden-Velocity Wings, FVWs) in the large-scale position-velocity diagrams of the HI surveys are thought to be associated with dynamical Galactic events. Most of the FVWs do not have counterparts in radio continuum or X-rays. The primary candidates of these FVWs with previously unknown nature are rapidly expanding HI shells of the old Galactic supernova remnants, which are too faint to be visible in other frequencies. We present preliminary results of a search for FVWs in the I-GALFA survey, which has the unprecedented sensitivity and resolution. About 40 FVWs have been identified in the Galactic Plane, 70% of which are smaller and fainter than the previously identified FVWs and are not associated with the known Galactic objects. We present their statistical properties and the HI images of some interesting FVWs.

Progress On A New Catalog Of Intermediate Velocity Clouds Using The Leiden-Argentina-Bonn HI Allsky Survey

Christopher M. Witt¹, B. Wakker², T. D. Engel¹, M. C. Gostisha¹, E. Thomson¹, L. Stratman¹, R. A. Benjamin¹

¹University of Wisconsin-Whitewater, ²University of Wisconsin-Madison.

Exhibit Hall

We present progress towards the creation of a new all-sky catalog of intermediate velocity clouds using the Leiden/Argentina/Bonn (LAB) Galactic HI survey. We have developed a Gaussian fitting program to fit individual spectra. Each spectra is initially fit automatically with a set of Gaussians, and then reviewed and adjusted, if necessary, by hand by our undergraduate team. When a satisfactory fit is found, it is submitted for review and adjustment by the senior team member. Intermediate clouds and complexes are formed by grouping Gaussian components by velocity and section of the sky. When complete, this will be the first all-sky catalog of intermediate velocity clouds, which can be compared to dynamical models of the Galactic fountain flows. We present preliminary results for the catalog in the sky with Galactic latitude greater than 45 degrees. This research was supported by NASA ATP grant NNX10AI70G to the University of Wisconsin-Whitewater.

251.31

A High Velocity Cloud Detected Towards M13

Barry Welsh¹, R. Lallement², J. Wheatley¹ ¹UC, Berkeley, ²LATMOS-IPSL, France.

Exhibit Hall

We present HST-COS observations of the interstellar sight-line towards the M13 globular cluster. High velocity gas at V \sim -120 km/s and intermediate velocity gas at V \sim -65 km/s has been detected in many UV absorption lines. The HVC gas is probably associated with the Complex K IVC with a distance of 1.0 < z < 4.7 kpc. This would place the infalling HVC gas far closer than previous estimates of HV clouds surrounding our Galaxy.

252

LSST Posters Poster Session *Exhibit Hall*

252.01

LSST Observatory and Science Opportunities

Zeljko Ivezic¹, M. A. Strauss², J. A. Tyson³, T. Axelrod⁴, J. S. Bloom⁵, LSST Collaboration ¹Univ. of Washington, ²Princeton Univ., ³Univ. of California Davis, ⁴Univ. of Arizona, ⁵Univ. of California Berkeley.

Exhibit Hall

The LSST design is driven by four science themes: dark energy, Galactic structure, transient objects, and the search for near-Earth asteroids. The LSST will carry out a ten-year imaging survey of 20,000 sq.deg. of the sky in six broad optical bands, with a deep stack reaching r~27.5 (5 sigma, point source). The current design, with an 8.4m (6.7m effective) primary mirror and a 9.6 square degree field of view, will allow about 10,000 square degrees of sky to be imaged to an effective depth of r=24.5 every three nights. The resulting petabytes of data will be made available to the US and Chilean communities for scientific investigations ranging from the properties of near-Earth asteroids, to characterizations of dark energy from strong and weak lensing, galaxy clustering, and distant supernovae. Eleven LSST Science Collaborations are actively laying the groundwork for first light: working on image analysis algorithms

and database design, exploring cadence choices, developing commissioning plans, and outlining scientific opportunities. These Collaborations have over 200 members to date, with membership open to the US community via an application process administered by NOAO.

252.02

The LSST: A System of Systems

Chuck F. Claver¹, G. P. Debois-Felsmann², F. Delgado³, P. Hascall², S. Marshall⁴, M. Nordby², G. Schumacher³, J. Sebag⁵, LSST Collaboration

¹NOAO/LSST, ²SLAC National Accelerator Laboratory, ³Cerro Tololo Interamerican Observatory, Chile, ⁴SLAC National Acceperator Laboratory, ⁵National Optical Astronomy Observatory. Exhibit Hall

The Large Synoptic Survey Telescope (LSST) is a complete observing system that acquires and archives images, processes and analyzes them, and publishes reduced images and catalogs of sources and objects. The LSST will operate over a ten year period producing a survey of 20,000 square degrees over the entire [Southern] sky in 6 filters (ugrizy) with each field having been visited several hundred times enabling a wide spectrum of science from fast transients to exploration of dark matter and dark energy. The LSST itself is a complex system of systems consisting of the 8.4m 3-mirror telescope, a 3.2 billion pixel camera, and a peta-scale data management system. The LSST project uses a Model Based Systems Engineering (MBSE) methodology to ensure an integrated approach to system design and rigorous definition of system interfaces and specifications. The MBSE methodology is applied through modeling of the LSST's systems with the System Modeling Language (SysML). The SysML modeling recursively establishes the threefold relationship between requirements, logical & physical functional decomposition and definition, and system and component behavior at successively deeper level of abstraction and detail. The LSST modeling includes the analysis and documenting the flow of command and control information and data between the suite of systems in the LSST observatory that are needed to carry out the activities of the survey. The MBSE approach is applied throughout all stages of the project from design, to validation and verification, though to commissioning.

252.03

LSST Operations Plan

Sidney Wolff¹, D. Silva², R. Blum², V. Krabbendam², J. Kantor¹, C. Smith³, A. Walker³ ¹LSST, ²NOAO, ³CTIO.

Exhibit Hall

The LSST will be operated in survey mode only. The primary goals of LSST operations are to: 1) maintain the end-to-end survey throughput at a level consistent with achieving the goals for the number of individual exposures at the level specified in the Science Requirements Document within 10 years; 2) achieve the specifications on image quality, photometric and astrometric accuracy, etc.; and 3) enable effective use of the data by a broad community of users. In order to maintain the cadence required, the observations, data processing, data quality assurance, archiving, and access for the community must all be highly automated. The LSST operations plan describes the operational model, the facilities required and their locations, and the services that will be provided.

252.04

LSST Education and Public Outreach

Suzanne H. Jacoby¹, K. D. Borne², G. Brissenden³, C. A. Christian⁴, A. A. Henden⁵, C. J. Lintott⁶, J. K. Olsen³, E. E. Prather³, M. J. Raddick⁷, D. M. Ratcliffe⁸, T. S. Spuck⁹, M. Subbarao¹⁰, G. Squires¹¹, LSST Outreach Advisory Board

¹LSST, ²George Mason University, ³University of Arizona, ⁴Space Telescope Science Institute, ⁵AAVSO,

⁶University of Oxford, United Kingdom, ⁷Johns Hopkins University, ⁸Wichita State University, ⁹Oil City High School, ¹⁰Adler Planetarium, ¹¹CalTech/IPAC.

Exhibit Hall

With its open data policy, survey mode of operations and data products with vast potential for discovery, LSST exemplifies the exponential growth of data volumes in astronomy and presents unprecedented opportunities for Education and Public Outreach (EPO). LSST will provide cyberinfrastructure and interfaces enabling users to visualize and interact with data in classrooms, science centers, and individual learning environments. We're building on new media technologies that emphasize collaboration, communication, and personalization with an emphasis on Citizen Science and authentic research experiences. We present plans, prototypes, and results of EPO efforts underway during LSST Design and Development.

252.05

LSST Telescope and Optics Status

Victor Krabbendam¹, W. J. Gressler¹, J. R. Andrew¹, J. D. Barr¹, J. DeVries¹, E. Hileman¹, M. Liang¹, D. R. Neill¹, J. Sebag¹, O. Wiecha¹, LSST Collaboration

¹NOAO/LSST.

Exhibit Hall

The LSST Project continues to advance the design and development of an observatory system capable of capturing 20,000 deg² of the sky in six wavebands over ten years. Optical fabrication of the unique M1/M3 monolithic mirror has entered final front surface optical processing. After substantial grinding to remove 5 tons of excess glass above the M3 surface, a residual of a single spin casting, both distinct optical surfaces are now clearly evident. Loose abrasive grinding has begun and polishing is to occur during 2011 and final optical testing is planned in early 2012. The M1/M3 telescope cell and internal component designs have matured to support on telescope operational requirements and off telescope coating needs. The mirror position system (hardpoint actuators) and mirror support system (figure actuator) designs have developed through internal laboratory analysis and testing. Review of thermal requirements has assisted with definition of a thermal conditioning and control system. Pre-cooling the M1/M3 substrate will enable productive observing during the large temperature swing often seen at twilight. The M2 ULE[™] substrate is complete and lies in storage waiting for additional funding to enable final optical polishing. This 3.5m diameter, 100mm thick meniscus substrate has been ground to within 40 microns of final figure. Detailed design of the telescope mount, including subflooring, has been developed. Finally, substantial progress has been achieved on the facility design. In early 2010, LSST contracted with ARCADIS Geotecnica Consultores, a Santiago based engineering firm to lead the formal architectural design effort for the summit facility.

252.06

Performance of the LSST Camera

D. Kirk Gilmore¹

¹Stanford/KIPAC.

Exhibit Hall

The LSST camera will be the largest digital camera ever built. As such, its design presents a number of challenges. The field of view will be 3.5 degrees in diameter and will be sampled by a 3.2 billion pixel array of sensors. The entire array will be read-out in under 2 seconds, which all lead to demanding constraints on the sensor architecture and the read-out electronics. In addition, given the fast, optical beam (f/1.2), the camera tolerances on the assembly and alignment of the focal plane and optics are tight. The camera also incorporates three large refractive lenses, an array of five, wide-band large filters mounted on a carrousel, and a mechanical shutter. We present an overview of the baseline camera

design, with an emphasis on the requirements and expected performance of the design that will allow the camera to meet its scientific objectives.

252.07

End-to-End Simulations of the LSST System

K. Simon Krughoff¹, Z. Ahmad², J. Bankert², D. Bard³, A. J. Connolly¹, C. Chang⁴, R. R. Gibson¹, K. Gilmore⁴, E. Grace², M. Hannel², J. G. Jernigan⁵, L. Jones¹, S. M. Kahn⁴, S. Lorenz², S. Marshall⁴, S. Nagarajan², J. R. Peterson², J. Pizagno¹, A. P. Rasmussen⁴, M. Shmakova³, N. Sylvestre¹, N. Todd², M. Young²

¹University of Washington, ²Purdue University, ³KIPAC/SLAC, ⁴Stanford/SLAC, ⁵SSL/UC Berkeley. Exhibit Hall

Efficient use of the data produced by the Large Synoptic Survey Telescope (LSST) will require comprehensive *a priori* knowledge of the impact of telescope design and implementation on the resulting catalogs and images. This includes gross characteristics like per band detection limits (coadded and single frame), as well as fine grained information such as point spread function behavior as a function of focal plane position and limits on the ability of the imaging system and reduction pipelines to accurately determine galaxy shapes. The LSST Image Simulation group is leading the effort to simulate the LSST system from end-to-end to high fidelity. Input catalogs including source variability, moving objects, and cosmological transients are matched to the LSST survey depth of r=28. These catalogs can be used to produce simulated images for excersizing the data reduction pipelines as well as simulated catalogs for calibration, moving object detection, and probing proposed science questions. We present the progress toward end-to-end simulation of the LSST system.

252.08

Visualization of Simulated LSST Images

Stuart L. Marshall¹, J. Jernigan², S. K. Kahn¹, A. Connolly³, J. R. Peterson⁴, Z. Ahmad⁴, J. Bankert⁴, D. Bard¹, C. Chang¹, R. Gibson³, K. Gilmore¹, E. Grace⁴, M. Hannel⁴, L. Jones³, S. Krughoff³, S. Lorenz⁴, S. Nagarajan⁴, J. Pizagno³, A. P. Rasmussen¹, M. Shmakova⁵, N. Sylvestre³, N. Todd⁴, M. Young⁴ ¹Stanford/SLAC, ²SSL/UC Berkeley, ³U. Washington, ⁴Purdue, ⁵KIPAC/SLAC. Exhibit Hall

The Image Simulation team for the Large Synoptic Survey Telescope (LSST) will show a series of sample images for a portion of the full field of view at a resolution of one LSST pixel (0.2 arc second) matching one pixel of a large 6000 x 6000 pixel display that is 7 x 7 feet in size. One full LSST field of view is composed of ~3 billion pixels, meaning that the large display can only show about 1.2 percent of the full field. This full resolution image corresponds to a square with a side that matches ~11 percent of the diameter of the full field. We will also display example full field of view images that include all stars, galaxies and moving objects near the threshold of detection for a 15 second exposure, and zoom in on 6000 X 6000 pixel (20 x 20 arc minute) regions of interest. In addition to these high resolution images, we will present a dynamic movie of the process of simulating each photon. Also we will show a full sky visualization of the catalog and stars, galaxies and moving objects that provide the input for the Monte Carlo image simulator for LSST.

LSST Astroinformatics And Astrostatistics: Data-oriented Astronomical Research

Kirk D. Borne¹, K. Stassun², R. J. Brunner³, S. G. Djorgovski⁴, M. Graham⁴, J. Hakkila⁵, A. Mahabal⁴, M. Paegert², M. Pesenson⁴, A. Ptak⁶, J. Scargle⁶, LSST Informatics and Statistics Team ¹George Mason Univ., ²Vanderbilt U., ³U. Illinois, ⁴Caltech, ⁵College of Charleston, ⁶NASA. Exhibit Hall

The LSST Informatics and Statistics Science Collaboration (ISSC) focuses on research and scientific discovery challenges posed by the very large and complex data collection that LSST will generate. Application areas include astroinformatics, machine learning, data mining, astrostatistics, visualization, scientific data semantics, time series analysis, and advanced signal processing. Research problems to be addressed with these methodologies include transient event characterization and classification, rare class discovery, correlation mining, outlier/anomaly/surprise detection, improved estimators (e.g., for photometric redshift or early onset supernova classification), exploration of highly dimensional (multivariate) data catalogs, and more. We present sample science results from these data-oriented approaches to large-data astronomical research. We present results from LSST ISSC team members, including the EB (Eclipsing Binary) Factory, the environmental variations in the fundamental plane of elliptical galaxies, and outlier detection in multivariate catalogs.

252.10

Inventorying the Solar System with LSST

R. Lynne Jones¹, M. E. Brown², P. A. Abel³, S. R. Chesley⁴, J. Durech⁵, Y. R. Fernandez⁶, A. W. Harris⁷, M. J. Holman⁸, Z. Ivezic⁹, R. Jedicke¹⁰, M. Kaasalainen¹¹, N. A. Kaib¹², Z. Knevezic¹³, A. Milani¹⁴, A. Park¹⁵, D. Ragozzine⁸, S. T. Ridgway¹⁶, D. E. Trilling¹⁷, B. Vrsnak¹⁸, LSST Solar System Science Collaboration ¹Univ. of Washington, ²CalTech, ³PSI/NASA Johnson, ⁴JPL, ⁵Charles University, Czech Republic, ⁶University of Central Florida, ⁷Space Science Institute, ⁸Center for Astrophysics, ⁹Univ. of Washington, University of Zagreb, ¹⁰Institute for Astronomy, ¹¹University of Helsinki, Finland, ¹²CITA, Canada, ¹³Astronomy Observatory Belgrade, Serbia, ¹⁴University of Pisa, Italy, ¹⁵University of Victoria, Canada, ¹⁶NOAO, ¹⁷Northern Arizona University, ¹⁸Hvar Observatory, Croatia.

Exhibit Hall

Near the ecliptic, LSST is expected to detect approximately 4000 moving objects per 9.6 square degree field of view. Each pointing (with mag limits r~24.5) will be revisited within 30-45 minutes, several times per month. Automated software will provide the means to link these individual detections into orbits. The result will be publicly available catalogs of hundreds of thousands of NEOs and Jupiter Trojans, millions of asteroids, tens of thousands of TNOs, as well as thousands of other objects such as comets and irregular satellites of the major planets. These catalogs will contain final orbits as well as the individual (multi-color) observations, calibrated to high precisision in astrometry (~50 mas) and photometry (~0.01 mag).

With these large datasets, LSST will provide new insights into links between populations of moving objects, such as the relationship between Main Belt asteroids and NEOs. Models of solar system evolution, such as the Nice model, can be tested against an order of magnitude larger statistical sample, providing much stronger constraints than are currently possible. With high accuracy multi-color photometry, lightcurves and colors will be determined for a significant fraction of the objects detected. Using sparse lightcurve inversion, spin state and shape models will be derived for tens of thousands of main belt asteroids. Derivation of proper elements for Main Belt asteroids will greatly enlarge existing asteroid families, particularly at smaller sizes, and precise color information will facilitate further division. More unpredictable discoveries, such as the potential for observing a real-time collision, could lead to new insights into physical properties, the size distribution at very small diameters, the orbital evolution of asteroids, or the discovery of possible space mission targets.

252.11 Comet Science with LSST Michael Solontoi¹, Ž. Ivezić², L. Jones²

¹Adler Planetarium, ²University of Washington. Exhibit Hall

The LSST will detect an unprecedented number (~10,000) of comets to r=24.5 over a ten year time frame. We simulate characteristic comet orbits through the LSST observational cadence and demonstrate that the LSST will observe individual Jupiter Family Comets (JFC) hundreds of times over their entire orbit, tracing each comet's evolution from presumed dormancy at large heliocentric distances, through the onset of out-gassing, and then back to inactivity. Simulations of Long Period Comets predict that LSST will make dozens of observations of each such comet, either on their way into and out of the Solar System, allowing in many cases early detection of these objects, or a number of observations while passing through perihelion, where the comets are the most active and variable.

252.12

Exploring the Transient and Variable Universe with LSST

Andrew C. Becker¹, J. S. Bloom², L. M. Walkowicz², LSST Collaboration

¹Univ. of Washington, ²University of California, Berkeley.

Exhibit Hall

LSST's real-time image processing pipeline is expected to release tens of thousands of variability alerts per night. Many of these alerts will be associated with previously known classes of Galactic and cosmological variability. However, with LSST's novel combination of areal coverage, photometric depth, and rapid time sampling, new classes of phenomena will be uncovered. To recognize them, we must first characterize the menagerie of known transient and variable phenomena as they will be seen by LSST. We report here on efforts to model the signatures of astrophysical variability using the operational and image simulation tools being developed by LSST. This includes the injection of variable flux, at the pixel level, into simulated LSST images, and the measurement of this signal using the LSST Data Management stack. We also address LSST's potential capability to serve as a localization resource for alerts issued by gravity wave experiments, whose effective beam size is well-matched to LSST's field of view. This opportunity for trans-spectral astrophysics requires interrupt and follow-up capabilities in the LSST scheduler, as well as well-defined conditions to trigger them.

252.13

Measuring RR Lyrae Stars Throughout the Local Group with LSST

Hakeem Oluseyi¹, A. Becker², C. C. Culliton³, M. Furqan¹, K. L. Hoadley¹, P. Regencia¹, A. J. Wells¹, I. J. Allison⁴, S. Jacoby⁵, Z. Ivezic², L. Jones², S. Krughoff², B. Sesar⁶

¹Florida Institute of Technology, ²University of Washington, ³Pennsylvania State University, ⁴Alabama A&M University, ⁵LSST Corporation, ⁶California Institute of Technology. Exhibit Hall

We report on a study to determine the efficiency of the Large Synoptic Survey Telescope to recover the periods and shapes of RR Lyrae light curves, and their brightnesses. We select the smoothed light curves of 40 such stars observed by the Sloan Digital Sky Survey in the "Stripe 82" region, 30 of type RRab and 10 of type RRc, that evenly sample the known period-shape relationship for these stars. We place each of these in 1007 fields across the sky, each of which represents a different realization of the LSST sampling cadence, and that sample 5 particular observing modes. A light curve simulation tool was used to sample the RR Lyrae light curves, returning each as it would have been observed by LSST, including realistic limiting magnitudes and photometric scatter. We report here the brightness, period, Fourier-shape, and template-shape recovery as a function of distance from ~ 75 kpc to ~ 2 Mpc, with survey

lengths varying from one to ten years. We find that ten years of LSST data are sufficient to recover the pulsation periods with a precision exceeding 0.001% for ~ 90% of stars within ~ 380 kpc of the Sun for Universal Cadence (UC) fields, and out to ~ 760 kpc for Deep Drilling (DD) fields, with the limit for successful period recoveries extending out to ~ 1.5 Mpc. For virtually all stars that had their periods recovered, their Fourier-based light curve shape parameter phi-31 was recovered with sufficient precision to recover photometric metallicities to within 0.14 dex out to ~ 1 Mpc in both the UC and DD fields. We outline an observing strategy that will increase the efficiency of period recovery for the majority of variable phenomena likely to be observed by LSST.

252.14

Mapping Milky Way And Local Volume Structure With LSST

Marla C. Geha¹, B. Willman², J. Bochanski³, J. Bullock⁴, M. Catelan⁵, V. Debattista⁶, C. Grillmair⁷, A. Jordan⁵, M. Juric⁸, J. Kalirai⁹, N. Kallivayalil¹, P. McGehee⁷, D. Minniti⁵, R. Munoz¹, R. Roskar¹⁰, A. Sarajedini¹¹, J. Simon¹², J. Strader⁸, LSST MWLV Collaboration

¹Yale University, ²Haverford, ³Penn State, ⁴UC Irvine, ⁵PUC, Chile, Chile, ⁶UCLan, United Kingdom, ⁷IPAC/Caltech, ⁸CfA, ⁹STScI, ¹⁰University of Washington, ¹¹UFlorida, ¹²Carnegie Observatories. Exhibit Hall

The LSST will yield revolutionary, multi-dimensional maps of the Milky Way (MW) galaxy and its neighbors. With its planned 1000 epochs over 6 bands and a final limiting magnitude of r=27.5 (AB mag; 5-sigma), it will provide an excellent resource for mapping the structure and accretion history of the MW and beyond in a way that the present generation of surveys can only hint at. LSST is expected to catalog 10 billion stars, including photometric metallicities for the 200 million F/G stars within 100 kpc and map the tangential velocity field of stars bright than r=24 mag to at least 10 kpc (at 10 km/s precision) and as far as 25 kpc (at 60 km/s precision). Specific related science to be enabled by LSST includes: mapping the 3D distribution of dust in the MW's disk, including variations in RV; understanding the smooth distribution of stars in the MW and other nearby galaxies; understanding large-scale chemical gradients in the MW; discovering lumps and streams in metallicity and phase-space; inferring the mass distribution in the MW; discovering ultra-faint galaxies throughout the Local Volume.

252.15

The Stellar Populations of the Milky Way and Nearby Galaxies with LSST

Knut A. Olsen¹, K. Covey², A. Saha¹, T. C. Beers³, J. Bochanski⁴, P. Boeshaar⁵, P. Cargile⁶, M. Catelan⁷, A. Burgasser⁸, K. Cook⁹, S. Dhital⁶, D. Figer¹⁰, Z. Ivezic¹¹, J. Kalirai¹², P. McGehee¹³, D. Minniti⁷, J. Pepper⁶, A. Prsa¹⁴, A. Sarajedini¹⁵, D. Silva¹, J. A. Smith¹⁶, K. Stassun⁶, P. Thorman⁵, B. Williams¹¹, LSST Stellar Populations Collaboration

¹NOAO, ²Cornell University, ³Michigan State University/JINA, ⁴Penn State University, ⁵U.C. Davis, ⁶Vanderbilt University, ⁷Pontificia Universidad Católica, Chile, ⁸U.C. San Diego, ⁹LLNL, ¹⁰RIT, ¹¹University of Washington, ¹²STScI, ¹³IPAC/Caltech, ¹⁴Villanova University, ¹⁵University of Florida, ¹⁶Austin Peay State University.

Exhibit Hall

The LSST will produce a multi-color map and photometric object catalog of half the sky to r=27.6 (AB mag; 5-sigma) when observations at the individual epochs of the standard cadence are stacked. Analyzing the ten years of independent measurements in each field will allow variability, proper motion and parallax measurements to be derived for objects brighter than r=24.5. These photometric, astrometric, and variability data will enable the construction of a detailed and robust map of the stellar populations of the Milky Way, its satellites and its nearest extra-galactic neighbors--allowing exploration of their star formation, chemical enrichment, and accretion histories on a grand scale. For example, with geometric parallax accuracy of 1 milli-arc-sec, comparable to HIPPARCOS but reaching more than 10 magnitudes fainter, LSST will allow a complete census of all stars above the hydrogen-burning limit that are closer than 500 pc, including thousands of predicted L and T dwarfs. The LSST time sampling will identify and characterize variable stars of all types, from time scales of ~ 1 hr to several years, a feast for variable star astrophysics; LSST's projected impact on the study of several variable star classes, including eclipsing binaries, are discussed here. We also describe the ongoing efforts of the collaboration to optimize the LSST system for stellar populations science. We are currently investigating the trade-offs associated with the exact wavelength boundaries of the LSST filters, identifying the most scientifically valuable locations for fields that will receive enhanced temporal coverage compared to the standard cadence, and analyzing synthetic LSST outputs to verify that the system's performance will be sufficient to achieve our highest priority science goals.

252.16

Galaxy Evolution with LSST

Andrew Ptak¹, LSST Galaxies Collaboration

¹NASA/GSFC.

Exhibit Hall

LSST will be a unique tool to study the universe of galaxies. The database will provide photometry for 10¹⁰ galaxies, from the Local Group to thousands of z>6 galaxies. It will provide structural measurements and 6-band photometry for about 10⁹ galaxies, largely at z<1.5. The key goal of the LSST Galaxies Collaboration is to measure the multivariate properties of the galaxy population including trends with redshift and environment. This includes observed galaxy properties (luminosities, colors, sizes, and morphologies) as well as derived galaxy properties (stellar masses, ages, and star formation rates) and how the joint distribution of these galaxy properties depends on redshift and environment as measured on a wide range of scales. Galaxy formation is inherently stochastic, but is fundamentally governed by the statistical properties of the underlying dark-matter density field. Determining how the evolving multivariate galaxy properties and scaling relations depend on this density field, and on the distribution and evolution of dark matter halos, will connect the results of large surveys to theoretical models of structure formation and galaxy formation.

252.17

AGN Science with LSST

Robert Gibson¹, S. F. Anderson¹, D. R. Ballantyne², A. J. Barth³, W. N. Brandt⁴, R. J. Brunner⁵, G. Chartas⁶, P. Coppi⁷, W. de Vries⁸, M. Eracleous⁴, X. Fan⁹, A. G. Gray², R. F. Green¹⁰, Z. Ivezic¹¹, M. Lacy¹², P. Lira¹³, G. M. Madejski¹⁴, J. A. Newman¹⁵, G. T. Richards¹⁶, D. P. Schneider⁴, A. Seth¹⁷, O. Shemmer¹⁸, H. A. Smith¹⁷, M. A. Strauss¹⁹, E. Treister²⁰, D. E. Vanden Berk²¹

¹University of Washington, ²Georgia Tech, ³UC Irvine, ⁴Penn State, ⁵University of Illinois, ⁶College of Charleston, ⁷Yale, ⁸LLNL, ⁹Arizona, ¹⁰LBTO, ¹¹University of Washington, University of Zagreb, ¹²NRAO, ¹³Universidad de Chile, Chile, ¹⁴SLAC, ¹⁵University of Pittsburgh, ¹⁶Drexel University, ¹⁷CfA, ¹⁸University of North Texas, ¹⁹Princeton, ²⁰IfA, Hawaii, ²¹St. Vincent College.

Exhibit Hall

The LSST survey will dramatically increase the number of known active galactic nuclei (AGN), cataloging over 10 million AGN across more than 20,000 square degrees of sky. Time-domain coverage, a hallmark of the LSST survey, will enable powerful new AGN selection criteria, including the lack of proper motion and especially variability, in addition to color-based selection in deep, coadded ugrizy (320--1090 nm) images. Most of the LSST sky will be observed about 1000 times over ten years, while AGN in "deep drilling" fields will receive intense monitoring on time scales of minutes to days. Distinguishing traits of the LSST AGN survey include its coverage of the luminosity-redshift plane, its reach to high redshifts (with over 1000 AGN at z > 6.5), and the use of difference imaging to detect faint AGN surrounded by

host galaxy emission or in crowded environments that challenge traditional photometry. LSST AGN will be used to determine the accretion history of supermassive black holes over cosmic time, the interaction of AGN with their evolving host galaxies and environments, the physics of AGN emission revealed by variability, and the relationship between AGN and dark matter through measurements of clustering at high redshifts. Multiwavelength analyses will benefit from matching LSST source identifications, redshifts, and light curves to archives and contemporaneous missions, and real-time LSST alerts will trigger follow-up observations. Simulated LSST images and archived SDSS Stripe 82 data are now being used to demonstrate the capabilities of the LSST AGN survey, with a current emphasis on evaluating metrics that select AGN based on their variability.

252.18

Simulating Galaxies and Active Galactic Nuclei in the LSST Image Simulation Effort

James Pizagno¹, Z. Ahmad², J. Bankert², D. Bard³, A. Connolly¹, C. Chang⁴, R. R. Gibson¹, K. Gilmore⁵, E. Grace², M. Hannel², J. G. Jernigan⁶, L. Jones¹, S. M. Kahn⁴, S. K. Krughoff¹, S. Lorenz², S. Marshall⁴, S. M. Shmakova³, N. Sylvestri¹, N. Todd², M. Young²

¹University of Washington, ²Purdue University, ³Kavli Institute for Particle Astrophysics & Cosmology, ⁴Stanford University, ⁵University of Stanford, ⁶Space Science Laboratory. Exhibit Hall

We present an extragalactic source catalog, which includes galaxies and Active Galactic Nuclei, that is used for the Large Survey Synoptic Telescope Imaging Simulation effort. The galaxies are taken from the De Lucia et. al. (2006) semi-analytic modeling (SAM) of the Millennium Simulation. The LSST Image Simulation effort requires full SED information and galaxy morphological information, which is added to the catalog by fitting Bruzual & Charlot (2003) stellar population models, with Cardelli, Clayton, Mathis (1989) dust models, to the BVRIK colors provided by the De Lucia et. al. (2006) SAM. Galaxy morphology is modeled as a double Sersic profile for the disk and bulge. Galaxy morphological information and number counts are matched to existing observations. The catalog contains galaxies with a limiting rband magnitude of $m_r=28$, which results in roughly 1E6 galaxies per square degree. An existing AGN catalog (MacLeod et. al. 2010) is matched to galaxy hosts in the galaxy catalog using SDSS observations. AGN are morphologically modeled as variable point sources located at the center of the host galaxy. We demonstrate how this extragalactic source catalog allows LSST to plan for extended object extraction, variable extragalactic source detection, sensitivity level determination after image stacking, and perform various other cosmological tests.

252.19

Baryon Acoustic Oscillations in the LSST Photometric Survey

Alexandra Abate¹, A. Gorecki², R. Ansari¹, A. Barrau², S. Baumont², L. Derome², E. Gawiser³, C. Magneville⁴, M. Moniez¹, J. A. Newman⁵, J. A. Tyson⁶, H. Zhan⁷, LSST LSS Science Collaboration ¹Laboratoire De L'Accelerateur Lineaire, IN2P3-CNRS, Universite de Paris-Sud, France, ²Laboratoire de Physique Subatomique et de Cosmologie, CNRS/UJF/INPG, France, ³Rutgers, the State University of NJ, ⁴CEA, DSM/IRFU, Centre d'Etudes de Saclay, France, ⁵University of Pittsburgh, ⁶University of California, Davis, ⁷National Astronomical Observatories, Chinese Academy of Sciences, China. Exhibit Hall

Baryon acoustic oscillation (BAO) studies provide an important probe of dark energy, yielding constraints that are highly complementary to other methods such as weak gravitational lensing and very competitive to other proposed large surveys. By measuring the BAO scale in ugrizy-band photometric redshift-selected samples, LSST will determine the angular diameter distance to each of a dozen redshifts with percent-level errors. However, photometric redshift (a.k.a. photo-z) errors can dilute the observed strength of the BAO signal. We therefore investigate the impact of simulated photo-z errors on

the reconstruction of the BAO scale using Monte Carlo simulations of mock galaxy samples with luminosity-color-redshift distributions designed to agree with those from the GOODS survey. In this poster, we demonstrate the effects that (i) the level of statistical uncertainty in photo-z's, (ii) the fraction of catastrophic photometric redshift outliers, or (iii) the choice of galaxy sample population has on the significance with which the BAO signal is detected.

252.20

Tracing the Supernovae of LSST

W. Michael Wood-Vasey¹, R. Kessler², R. Biswas³, D. Cinabro⁴, B. Dilday⁵, S. Kuhlmann³, LSST Supernova Collaboration

¹University of Pittsburgh, ²University of Chicago, ³Argonne National Lab, ⁴Wayne State, ⁵Las Cumbres Observatory Global Telescope.

Exhibit Hall

The LSST will discover over one million supernovae during its 10-year survey. This overwhelming compendium of stellar death throes will allow for novel techniques and insights in our study of the evolution of the Universe, large-scale structure, supernova explosion physics, and star formation and evolution.

We here present our most detailed simulations to date of the lightcurves and properties of the supernovae that will be found by LSST using the LSST operations and cadence simulation and the SNANA supernova survey modeling code. The largest uncertainty in our results is due to the lack of large samples of non-Type Ia supernovae and the uncertainty in the type-dependent supernovae rate as a function of redshift. We argue for increased observations of all types of supernovae in the nearby Universe and programs to investigate what spectroscopic subsamples will be necessary to enable photometric classification of the supernovae to be found by LSST.

252.21

Strong Lenses with LSST: Simulated 10-year Movies of Multiply-Imaged Quasars

Jesse Garrett Jernigan¹, P. J. Marshall², M. Oguri³, R. Gibson⁴, J. Pizagno⁴, A. Connolly⁴, J. R. Peterson⁵, Z. Ahmad⁵, J. Bankert⁵, D. Bard⁶, C. Chang⁷, E. Grace⁵, K. Gilmore⁸, M. Hannel⁵, L. Jones⁴, S. M. Kahn⁸, S. Krughoff⁴, S. Lorentz⁵, S. Marshall⁸, S. Nagarajan⁵, A. P. Rasmussen⁸, M. Shmakova⁶, N. Sylvestre⁴, N. Todd⁵, M. Young⁵, LSST Strong Lensing Science Collaboration

¹Space Sciences Laboratory, UC Berkeley, ²Oxford/KIPAC, United Kingdom, ³NAOJ, Japan, ⁴U. Washington, ⁵Purdue, ⁶KIPAC/SLAC, ⁷Stanford, ⁸Stanford/SLAC.

Exhibit Hall

We use the LSST image simulator to generate realistic 10-year datasets for 100 of the strong galaxy-scale gravitational lenses expected to be measurable with the universal survey data. The 200 mock i-band images have sky brightness and atmospheric seeing drawn from plausible distributions for the Cerro Pachon site, and we use plausibly varying telescope optics and detector response to fully represent the expected image quality. Passing the simulated images through a standard astronomical object detection pipeline gives us our first view of what these rare and valuable objects will look like in the LSST database. We also investigate the recovery of the input lightcurves.

Accurate Cosmography with LSST Time Delay Lenses

Philip J. Marshall¹, C. P. Sandford², C. D. Fassnacht³, D. R. Meldgin³, M. Oguri⁴, S. H. Suyu³, M. W. Auger³, LSST Strong Lensing Science Collaboration

¹Stanford University, ²Imperial College, United Kingdom, ³University of California, ⁴NAOJ, Japan. Exhibit Hall

LSST will discover several thousand lensed quasars and supernovae, and provide high signal-to-noise ratio, well-sampled lightcurves for each. We explore the potential of the expected sample of 400 well-measured 4-image (quad) lens systems for constraining cosmological parameters, via measurements of the "time delay distance" to each one. Based on recent experience with individual lenses studied in great detail with the VLA, Keck and HST, we make plausible assumptions about our likely knowledge of the lens model and lens environment to quantify the largest sources of systematic error, and use simulations of LSST lightcurves to estimate the expected time delay precision. We find that the resulting constraints on the parameters of the Dark Energy equation of state are competitive with and complementary to those from other LSST cosmological probes.

252.23

Probing Dark Energy with Weak Lensing with LSST

Ian P. Dell'Antonio¹, D. Wittman², B. Jain³, J. Bosch², D. Clowe⁴, M. Jarvis³, M. Jee², J. Tyson², H. Zhan⁵, LSST Weak Lensing Science Collaboration

¹Brown University, ²UC Davis, ³Univ. of Pennsylvania, ⁴Ohio University, ⁵NAOC, China. Exhibit Hall

LSST will measure the shape, magnitude, and colors of more than $3x10^9$ galaxies over 20,000 square degrees. These data will be used in several complementary ways to measure the properties of dark energy. Reconstruction of the shear power spectrum on linear and non-linear scales $I^/< 2000$, and of the cross-correlation of shear measured in different photometric redshift bins, provides a constraint on the evolution of dark energy that is complementary to the purely geometric measures provided by Supernovae and BAO. Combining weak lensing and BAO measurements breaks degeneracies and results in tighter constraints on dark energy than each method can provide individually. Cross-correlation of the shear and galaxy number density signal within redshift shells minimizes the sensitivity to photo-z errors. Measurements of the shear bispectrum constrain dark energy and allow an independent test of theories of gravity.

In addition to the galaxy shape correlations, LSST will detect ~ 50,000 shear peaks with significance greater than 4σ , and ~ 10,000 securely detected clusters of galaxies with line-of-sight velocity dispersions greater than 700 km/s. These allow independent constraints on the dark energy signature in the growth of structure. Tomographic study of the shear of background galaxies as a function of redshift allows the a geometric test of dark energy to be extracted from the weak lensing data. Finally, lensing signatures beyond the shear (magnification and flexion) will be accessible with LSST with unprecedented statistical power.

The ability of LSST to extract the dark energy signal will depend on the accuracy with which the stellar PSF can be determined, and on the unbiased reconstruction of object shapes from long sequences of exposures in which the objects are detected at low significance. We discuss the prospects for cosmological constraints from weak lensing studies with LSST.

Weak Lensing Galaxy Shear Extraction Testing for LSST

Myungkook J. Jee¹, J. A. Tyson¹, D. Wittman¹, A. J. Connolly², G. Jernigan³, J. R. Peterson⁴, Z. Ivezic² ¹UC Davis, ²U. Washington, ³UC Berkeley, ⁴Purdue U..

Exhibit Hall

The accuracy and reliability of weak-lensing measurement for LSST depend on the level of the atmospheric turbulence of the site, the integrity of the design and fabrication of the optical system, the ability to describe and model both the atmospheric and instrumental characteristics, and the accuracy of the algorithm to remove these systematics and extract gravitational shears of galaxies. Of course, at the core of this removal of the systematics is the high-fidelity modeling and correction of the point spread function (PSF) on the delivered images.

In this poster, we present the results of our on-going end-to-end shear extraction simulation efforts to investigate the impacts of the above factors on lensing signal measurement. First, we review our past accomplishments on the issue of accurate description and removal of the PSF effects using a principal component analysis method. Then, we present the results of our current shear extraction simulation using artificially sheared galaxy images. Finally, we discuss some key issues that need to be addressed in order to meet the requirement of the LSST weak-lensing science.

252.25

Shear Systematics in LSST Simulated Images

Chihway Chang¹, S. M. Kahn¹, G. Jernigan², J. R. Peterson³, A. P. Rasmussen¹, Z. Ahmad³, J. Bankert³, D. Bard¹, A. Connolly⁴, R. R. Gibson⁴, K. Gilmore¹, E. Grace³, M. Hannel³, L. Jones⁴, S. Krughoff⁴, S. Lorenz³, S. Marshall¹, S. Nagarajan³, J. Pizagno⁴, M. Shmakova¹, N. Sylvestre⁴, N. Todd³, M. Young³ ¹SLAC/Stanford, ²SSL/UC Berkeley, ³Purdue University, ⁴U. Washington. Exhibit Hall

The Large Synoptic Survey Telescope (LSST) is a large-aperture, wide-field, ground-based telescope designed to provide a complete survey of 20,000 square degrees of sky in six optical bands every few nights. Over ten years of operation, it will measure the magnitudes, colors, and shapes of several billion galaxies. As such, LSST will probe cosmic shear down to levels far beyond those accessible with current surveys. The unprecedented statistical power of LSST will impose new requirements on the control of weak lensing systematics. Various noise sources become important in this context, associated with counting statistics, atmospheric effects, and wavefront errors introduced by the telescope and camera systems.

We are studying these various noise components and their impact on shear measurements using simulated LSST images produced by a prototype high fidelity photon-by-photon Monte Carlo code. The code includes the most significant physical effects associated with photon propagation through the atmosphere, reflection off of the three mirror surfaces of the telescope, and propagation through the elements of the camera and on into the detector. We report on preliminary results from this program, including plots of residual shear error correlation functions due to errors in the object shape estimation for realistic LSST operating conditions.

253 *Exoplanet Detection: Techniques & Observations* Poster Session *Exhibit Hall*

253.01

HATSouth Operations and Data Processing

Kaloyan Penev¹, Z. Csubry², G. Bakos²

¹Harvard Univ., ²Harvard Smithsonian Center for Astrophysics.

Exhibit Hall

The HAT-South network consists of three pairs of identical, fully automated, wide-field telescopes, each equipped with 4 optics and CCDs forming a mosaic image. The instruments are located at Las Campanas in Chile, Siding Springs in Australia, and the HESS site in Namibia, and are jointly operated by the CfA, MPIA and ANU. Its primary purpose is to search for and characterize extra-solar planets around nearby bright stars. In this presentation I will discuss two aspects of the HAT-South system.

First, in order to achieve the high photometric precision necessary for detecting transiting planets, the observing systems needs to be as stable as possible to minimize systematic noise. Here I will detail the methods used, and the current performance of the fully automated pointing and focus corrections applied during observations.

Second, I will present the frame calibration procedure, and the various diagnostics generated that allow us to monitor the health and performance of such a remote and wide-spread system of telescopes.

253.02

Hat-south: A Global Network Of Wide Angle Telescopes Searching For Transiting Extrasolar Planets Around Bright Stars

Gaspar Bakos¹, Z. Csubry¹, K. Penev¹, C. Afonso², D. Bayliss³, B. Beky¹, P. Conroy³, B. Csak², T. Henning², A. Jordan⁴, G. Kovacs⁵, J. Lazar⁶, R. Noyes¹, I. Papp⁶, M. Rabus⁴, P. Sackett³, P. Sari⁶, D. Sasselov¹, B. Schmidt³, V. Suc⁴, K. Ueltzhoeffer²

¹Harvard-Smithsonian Center for Astrophysics, ²MPIA, Germany, ³ANU, Australia, ⁴PUC, Chile, ⁵U. Cambridge, United Kingdom, ⁶Hungarian Astronomical Association, Hungary. Exhibit Hall

HAT-South is the first global network dedicated to searching for transiting planets. With stations in Chile, Australia, and Namibia (managed by CfA/PUC, ANU and MPIA, respectively), it provides a unique, high precision, 24-hour data-stream on stars brighter than 14th magnitude. The HAT-South instruments were installed in 2009, and the network began preliminary operations in 2010. Each site hosts a pair of telescope mounts, and each mount is equipped with four 0.18m diameter, f/2.8 reflectors and four 4Kx4K CCDs. This yields a 8x8 degree mosaic field per mount, imaged onto 64 megapixels. We describe further details of the instrument in our poster, including the instrument control software environment responsible for the fully automated operations. We also summarize the first year of operations, data-flow, initial performance, and early results.

253.03

Modeling the Detectability of Exoplanets for the Palomar PALM3000 Extreme Adaptive Optics System Rahul Patel¹, S. Metchev¹

¹Stony Brook University.

Exhibit Hall

In this study we present the projected capabilities and detection limitations for the PALM3000 extreme adaptive optics system to directly image super-Jupiter planets around nearby stars. Commissioning for the PALM3000 is planned for the summer of 2011. Probability for a detection was modeled using a

Monte-Carlo simulation written in IDL. The contrast curve relation with Palomar's detection limits in the H-band was used as the constraint for detection of a randomly sampled planet with a mass, eccentricity, and distance on the semi-major axis, around a randomly sampled star with a given mass, age, and distance from Earth.

253.04

Measuring Radial Velocities in R-band with Telluric Line Calibration

Sara Gettel¹, P. Zielinski², G. Nowak², C. Bender¹, A. Wolszczan¹, J. Wright¹ ¹Pennsylvania State Univ., ²Torun Center for Astronomy, Poland. Exhibit Hall

The iodine gas cell is replaced by the telluric O2 and water vapor lines to calibrate observations of RV stable M dwarfs made with the High Resolution Spectrograph of the Hobby-Eberly Telescope. Radial velocities are to be measured with both iodine lines in the visible and the atmospheric lines in the 6000-8800A region, as a first step in determining the utility of telluric lines as R-band radial velocity calibrators. Based on other published results, we expect that by modeling atmospheric effects in sufficient detail, a precision of <10 m s-1 is attainable. If feasible, this method will be used to search for Neptune-mass planets around K and M dwarfs.

253.05

Recent Results from the Princeton Occulter Testbed

Dan Sirbu¹, E. Cady², N. Kasdin¹

¹*Princeton University*, ²*Jet Propulsion Laboratory*.

Exhibit Hall

Direct imaging for detection of Earth-like exoplanets requires 10¹⁰ levels of starlight suppression in the optical system's PSF. Usage of an external occulter is one of prime candidate methods for a space-based high contrast imaging mission. At Princeton we have setup a subscale experiment to test theoretical predictions of the electric downstream from an occulter and usage of out-of-band information for sensing in support of formation flight. We present the experiment and latest results for high-contrast imaging with this system and out-of-band sensing for formation flight.

253.06

APOSTLE Observations of GJ 1214b: Constraints on System Parameters and Evidence for Stellar Activity

Praveen Kundurthy¹, E. Agol¹, A. C. Becker¹, R. Barnes¹, B. Williams¹

¹University of Washington.

Exhibit Hall

We present three transits of GJ 1214b, observed as part of the Apache Point Observatory Survey of Transit Lightcurves of Exoplanets (APOSTLE). We used our r-band (λ = 625nm) lightcurves in conjunction with previously gathered (longer wavelength) transit lightcurves of GJ 1214b to re-derive system parameters. By using parameters such as transit duration (t_7) and ingress/egress length (t_G), we were able to reduce the degeneracies in our transit model. This is a preferred condition for Markov Chain Monte Carlo techniques, which are typically used to quantify uncertainties in measured parameters. The joint analysis of this multi-wavelength dataset confirms earlier estimates of system parameters such as planetary orbital period, the planet-to-star radius ratio and stellar density. However, we show that estimates of the absolute radius and mass of the planet depend strongly on how the stellar mass and radius are determined. Planet radius and mass can range between 2.5-3.2 R_{earth}) and 6.4-8.5 M_{earth}) respectively; depending on whether we use stellar mass-radius or mass-luminosity relations. The lightcurves resulting from our milli-magnitude photometry also show features that may be attributed to stellar activity. During the first night we observed a 0.8% rise in the out-of-eclipse flux of

the host star lasting approximately 3 minutes. The trend has a characteristic fast-rise exponential decay shape commonly associated with stellar flares. During the second night we observed a minor brightening during the transit. Due to its symmetric shape we believe this feature might have been caused by the planet obscuring a star-spot on the stellar disk. Finally, from our derived transit times we find no evidence for transit timing variations in this system.

253.07

Numerical Design of Starshades

Amy Lo¹, T. Glassman¹, O. Bruno², J. Chaubell³, A. Johnson¹, D. Hoch² ¹Northrop Grumman Corporation, ²California Institute of Technology, ³Mathsys. Exhibit Hall

Starshades are a new concept to allow direct imaging and spectroscopy of terrestrial extrasolar planets around nearby stars. Diffraction around the apodized starshade suppresses light from the target star by more than 10 orders of magnitude, allowing observations of faint planets nearby. The large size of the starshade (10's of meters

in diameter) and low level of residual starlight present a challenge in calculating the performance of the starshade design. We present a highly accurate and efficient method for evaluation of the diffraction performance of the starshade: our algorithm can produce the exceedingly accurate intensity values needed for starshade design, for tens of thousands of points in the observation region, in a matter of seconds in a present-day single processor computer. We then apply this method to show how the starshade performance is related to its design and to derive a specific starshade design for the New Worlds Observer mission concept.

253.08

Improving the Radial Velocity Precision of HET/HRS

Xuesong Wang¹, J. T. Wright¹

¹Pennsylvania State University.

Exhibit Hall

We present our work on improving the radial velocity precision of the High Resolution Spectrograph (HRS) on Hobby-Eberly Telescope (HET). This stable, fiber-fed spectrograph had a reported RV precision of around 3-5 m/s. Upon HRS upgrades, combined with our improved procedures on spectral reduction and RV extraction, we have achieved 3m/s, and are pushing this limit towards 1m/s.

253.09

A Precision Radial Velocity Pathfinder Instrument in the H Band with a Laser Frequency Comb Ryan Terrien¹, S. Mahadevan¹, L. Ramsey¹, C. Bender¹, S. Redman¹, S. Osterman², S. Diddams³, G. Ycas³, F. Quinlan³, B. Botzer¹

¹Pennsylvania State University, ²University of Colorado, ³National Institute of Standards and Technology. Exhibit Hall

We describe changes to the warm-bench, fiber-fed, Penn State Pathfinder instrument that enabled us to test the ability to recover precision radial velocities in the H-band. The use of thermal blocking filters that cut off at ~1.7 microns allows us to observe in the H-band by blocking the overwhelming thermal flux beyond 2 microns. A PK-50 window provides further suppression of this thermal flux. We also describe the observations, reduction, and results from an August 2010 test run of this instrument with a 25 GHz NIST laser frequency comb calibration system. We obtained radial velocities of several bright stars with on-sky observation with the laser comb. Our results demonstrate the potential of our testbed configuration for obtaining precision radial velocities in the NIR, as well as the utility of laser frequency combs as wavelength calibrators in this wavelength regime.

The Gemini NICI Planet-Finding Campaign: Discovery of a Substellar L Dwarf Companion to a Nearby Young M Dwarf.

Zahed Wahhaj¹, M. C. Liu¹, B. A. Biller¹, F. Clarke², E. L. Nielsen³, L. M. Close³, M. Cushing⁴, T. Dupuy¹, T. L. Hayward⁵, M. Tecza⁶, N. Thatte⁶, M. Chun¹, C. Ftaclas¹, M. Hartung⁵, I. Reid⁷, E. L. Shkolnik⁸, S. H. P. Alencar⁹, P. Artymowicz¹⁰, A. Boss⁸, A. Burrows¹¹, E. Mamajek¹², E. de Gouveia Dal Pino¹³, J. Gregorio-Hetem¹³, S. Ida¹⁴, M. Kuchner¹⁵, D. Lin¹⁶, D. W. Toomey¹⁷

¹Institute for Astronomy, ²University of Oxford, United Kingdom, ³Steward Observatory, University of Arizona, ⁴Jet Propulsion Laboratory, ⁵Gemini Observatory, Southern Operations Center, Chile,

⁶Department of Astronomy, University of Oxford, United Kingdom, ⁷Space Telescope Science Institute, ⁸Department of Terrestrial Magnetism, ⁹Universidade Federal de Minas Gerais, Brazil, ¹⁰University of Toronto at Scarborough, Canada, ¹¹Department of Astrophysical Sciences, Princeton University, ¹²University of Rochester, ¹³Universidade de Sao Paulo, Brazil, ¹⁴Tokyo Institute of Technology, Japan, ¹⁵NASA Goddard Space Flight Center, ¹⁶Department of Astronomy and Astrophysics, University of California, ¹⁷Mauna Kea Infrared.

Exhibit Hall

We present the discovery of a substellar companion to a nearby M dwarf member of a young moving group. We detected the companion, at a separation of 75 AU, using the Near-Infrared Coronagraphic Imager (NICI) on the Gemini-South Telescope. Two epochs of NICI observations confirm that the companion is physically associated with the primary. Its ZJHK-band colors are similar to field late-M and L dwarfs. Near-IR spectra obtained with NIFS on the Gemini North Telescope indicate a spectral type of $L4 \pm 1$ with moderate to low surface gravity, including a triangular H-band continuum shape which appears intermediate between much younger and much older field objects. The absorption lines and bandpass continuum shapes match especially well the dusty field L4.5 dwarf 2MASS J22244381-0158521. We fit the NIFS spectra of the companion using Ames-Dusty model atmospheres and derive Teff =1700 - 1900 K and log(g) = 4.5 ± 0.5. The NIFS spectra also show that the radial velocities of A and B agree to within ±10 km/s, further confirming their physical association. Using the age and bolometric luminosity of the companion, we derive a mass of 27 ± 8 Mjup from the Lyon/Dusty evolutionary models. A photometric estimate of the metallicity of the primary star suggests perhaps a super-solar abundance, but a more precise distance to the system is needed. Altogether, our discovery represents one of the coolest young companions found to date, with a large projected separation making it an appealing substellar object for detailed follow-up studies.

253.11

Advanced Visible Nulling Coronagraph Test Bed Facility

Jagmit Sandhu¹, P. Irwin¹, M. Shao¹, J. Shaw¹, R. Smythe¹, B. Levine¹, R. Lyon² ¹Jet Propulsion Laboratory, ²NASA Goddard Spaceflight Center. Exhibit Hall

JPL is establishing a facility to advance the technology of visible nulling interferometry for exoplanet imaging at visible wavelengths. It's objective is to demonstrate stable broadband contrast at the level of 10⁻¹⁰ between the star and planet. The facility will demonstrate proof of concept control of the amplitude and phase of the light to achieve target performance levels. Key components such as a segmented deformable mirror, 16 bit electronics for deformable mirror control, and a coherent single mode fiber array have been integrated and are functional. We will show experimental results of our progress to date.

Design, Tolerancing and Prototyping of Starshades for Exoplanet Detection and Characterization N. Jeremy Kasdin¹, D. N. Spergel¹, D. Lisman², S. Shaklan², M. Thomson², L. Marchen², P. Dumont², D. Tenerelli³, B. Macintosh⁴, R. Rudd⁴, J. Mikula⁵

¹Princeton Univ., ²Jet Propulsion Laboratory, ³Lockheed Martin Corp., ⁴Lawrence Livermore National Laboratory, ⁵NASA Ames Research Center.

Exhibit Hall

Starshades provide the starlight suppression needed for detecting and characterizing exoplanets with a much simpler telescope and instrument than is required for the equivalent performing coronagraph. The key challenges with starshades are in deploying a large structure and controlling its shape within precise tolerances. The required tolerances are established by modeling the effect that various mechanical and thermal errors have on scatter in the telescope image plane and by suballocating the allowable contrast degradation between these error sources. We present a representative error budget consistent with detection and characterization of exo-earths and a starshade design that is tailored to satisfying these requirements. Prototype petals are in development at JPL and one will be integrated with an optical edge provided by Lockheed Martin as part of a Technology Demonstration for Exoplanet Missions study led by Princeton University. The TDEM activity includes a demonstration of the capability to achieve what is considered to be the most stringent requirement, the manufacturing tolerances on petal shape.

253.13

Searching For The Youngest Planets With CSHELL

Christopher Crockett¹, N. Mahmud², L. Prato¹, C. M. Johns-Krull², P. Hartigan², D. T. Jaffe³, C. A. Beichman⁴

¹Lowell Observatory, ²Rice University, ³University of Texas, ⁴NExSci. Exhibit Hall

We are using CSHELL at the IRTF to confirm the presence of giant planets in a sample of 1-3 Myr old T Tauri stars in the Taurus-Auriga low-mass star forming region. The presence of large, cool star spots makes this a challenging environment in which to conduct a traditional RV survey; optical RV amplitudes are typically hundreds of m/s from stellar activity alone. However, we can leverage the fact that spotinduced RV modulation is dependent of wavelength. We identify potential candidates based on initial optical observations obtained at McDonald Observatory, Kitt Peak, and through the Keck HIRES Archive. Bisector analysis helps us identify targets to continue observing in the K band where the spot noise is much lower. Companion-induced variability will have the same amplitude at both wavelengths. We present details on our methodology for determining NIR RVs using CSHELL; over a two year baseline, we achieve 60 m/s precision on RV standards. We also present progress in modeling how stellar parameters affect the optical-to-NIR RV contrast and analysis of several candidate planet hosts. Given the young ages of these targets, a positive detection will place one of the first observational constraints on the planet formation timescale.

253.14

Brown Dwarfs and Giant Planets Around Young Stars

Naved Mahmud¹, C. Crockett², C. Johns-Krull¹, L. Prato², P. Hartigan¹, D. Jaffe³, C. Beichman⁴ ¹*Rice University,* ²*Lowell Observatory,* ³*University of Texas,* ⁴*Jet Propulsion Laboratory, California Institute of Technology.*

Exhibit Hall

How dry is the brown dwarf (BD) desert at young ages? Previous radial velocity (RV) surveys have revealed that the frequency of BDs as close companions to solar-age stars in the field is extraordinarily low compared to the frequency of close planetary and stellar companions. Is this a formation or an
evolutionary effect? Do close-in BDs form at lower rates, or are they destroyed by migration via interactions with a massive circumstellar disk, followed by assimilation into the parent star? To answer these questions, we are conducting an RV survey of 130 T Tauri stars in Taurus-Auriga (a few Myr old) and a dozen stars in the Pleiades (100 Myr old) to search for stellar reflex motions resulting from close substellar companions. Our goal is to measure the frequency of BDs at young ages. Detecting a higher frequency of BDs in young systems relative to the field will provide evidence for the migration theory as well as set limits on the migration timescale. Two additional goals are (1) to investigate the effect of star spots in young stars on RV observations, and (2) to detect the youngest-known giant exoplanet.

We present results from the first few years of this survey. Strikingly, after completing observations of a third of our sample, we have yet to detect a single BD. Thus we can set limits on the dryness of the BD desert at young ages and shed light on the mysterious early lives of these objects.

254

Instrumentation: Space Missions Poster Session Exhibit Hall

254.01

Overview of the Cosmic Origins Spectrograph Performance After the 1st Year On-Orbit

Cristina M. Oliveira¹, T. Ake², A. Aloisi¹, W. Dixon³, P. Ghavamian¹, D. Massa¹, S. Niemi¹, R. Osten¹, I. Pascucci¹, C. Proffitt², D. Sahnow³, W. Zheng³, B. York¹

¹Space Telescope Science Institute, ²Space Telescope Science Institute/CSC, ³Johns Hopkins University. Exhibit Hall

The Cosmic Origins Spectrograph (COS) was installed on board the Hubble Space Telescope (HST) in May 2009 as part of the most recent servicing mission 4, and is a third-generation instrument that has significantly extended the HST UV spectroscopic capabilities. Here we highlight the current instrument performance, with particular emphasis on the calibrations performed during Cy 17. Plans for future improvements in the COS on-orbit calibration are also discussed.

254.02

Flux Calibration of the Cosmic Origins Spectrograph

Charles R. Proffitt¹, R. C. Bohlin², R. A. Osten², K. A. Bostroem², D. Massa², D. J. Sahnow³, P. Ghavmian², M. A. Wolfe²

¹STScI/CSC, ²STScI, ³STScI/JHU.

Exhibit Hall

We review the current status of the flux calibration of the Cosmic Origins Spectrograph (COS). The absolute flux calibration is ultimately tied to model atmosphere calculations for well studied DA white dwarf standards, but in practice a number of other effects have to be taken into account to properly calibrate individual observations. These include the time dependent throughput changes of each mode, variations of throughput with central wavelength setting, flatfielding issues, centering in the aperture, vignetting, and changes in detector gain. We discuss our understanding of each of these issues, how these effects can be corrected during calibration of COS data, and our plans for monitoring and improving the flux calibration of COS in the future.

Cosmic Origins Spectrograph Far-Ultraviolet Flat Fields

Michael A. Wolfe¹, T. B. Ake¹, D. Massa¹, S. Beland², S. Penton², D. Sahnow³, K. France², J. McPhate⁴ ¹STScI, ²University of Colorado, ³Johns Hopkins University, ⁴University of California. Exhibit Hall

The COS FUV detector is composed of two micro-channel plate (MCP) segments with cross delay line anodes. The detector displays a variety of localized, non-uniformities in its response, including hexagonal and moire patterns, dead spots, gain variations, and shadows from the wire grid used to increase MCPs quantum efficiency. These features produce fixed-pattern noise in COS FUV spectra. Typically, such irregularities are eliminated by dividing the raw data by a flat field image. Ground testing of the prelaunch flats revealed that the S/N did not improve and consequently an attempt was made during SMOV to construct a flat field image from external targets. However, it did not result in a flat field of sufficient quality to be used for standard CALCOS processing. In contrast, it has been demonstrated that the fixed pattern features can be largely eliminated in high S/N data by using the iterative FP-SPLIT algorithm (similar to the one used for GHRS and FOS data) to obtain COS spectra with a S/N > 100. A product of this approach is a "1-D flat" which characterizes the contribution of fixed pattern noise to the spectrum. We have begun to explore various methods for utilizing these 1-D flats to correct unrelated, individual exposures. Initial results have been encouraging, and the results the our study will be discussed.

254.04

Post-Servicing Mission 4 Flux Calibration of the STIS Echelle Modes

K. Azalee Bostroem¹, A. Aloisi¹, C. Proffitt¹, R. Osten¹, R. Bohlin¹

¹Space Telescope Science Institute.

Exhibit Hall

STIS echelle modes show a wavelength-dependent decline in sensitivity with time. While this trend is observed in all STIS spectroscopic modes, the echelle sensitivity is further affected by a time-dependent shift in the blaze function. To improve the echelle flux calibration, new baselines for the echelle sensitivities are derived from post-Servicing Mission 4 (SM4) observations of the Hubble Space Telescope standard star G191-B2B. We present how these baseline sensitivities compare to pre-failure trends. Specifically, where the new results differ from expectations and discuss anomalous results found in E140H monitoring observations are highlighted.

254.05

The Integration and Test Program of the James Webb Space Telescope

Randy A. Kimble¹, JWST Team

¹NASA's GSFC.

Exhibit Hall

With the delivery of its flight scientific instruments and the completion of all telescope optics both scheduled to occur later this year, the James Webb Space Telescope (JWST) will enter into a challenging integration and test (I&T) program. Highlights of that program include cryo-vacuum tests of the Integrated Science Instrument Module (ISIM) at Goddard Space Flight Center, ambient integration of the ISIM and the Optical Telescope Element (OTE) at Goddard, and an end-to-end cryo-vacuum test of the OTE + ISIM system at Johnson Space Center. We review the overall flow of the I&T program, highlighting the key activities and the critical verifications to be performed at each step.

PIAA Coronagraph Development at NASA Ames: High Contrast Laboratory Demonstration at 2 I/D Ruslan Belikov¹, E. Pluzhnik¹, F. C. Witteborn¹, D. H. Lynch¹, T. P. Greene¹, P. T. Zell¹, K. Balasubramanian², O. Guyon³

¹NASA Ames Research Center, ²NASA Jet Propulsion Laboratory, ³University of Arizona. Exhibit Hall

Coronagraph technology is advancing and promises to directly image and spectrally characterize extrasolar Earth-like planets in the foreseeable future (such as the 2020 decade) with a telescope as small as 1.5m. A small Explorer-sized telescope can also be launched in the 2010 decade capable of seeing debris disks as small as 10s of zodis and potentially a few large planets. The Phase Induced Amplitude Apodization (PIAA) coronagraph makes such aggressive performance possible. We report on the latest results from a testbed at NASA Ames that is focused on developing and testing the PIAA coronagraph. This laboratory facility was built in 2008 and is designed to be flexible, operated in an actively thermally stabilized air environment, and to complement collaborative efforts at NASA JPL's High Contrast Imaging Testbed. For our wavefront control we are using small Micro-Electro-Mechanical-System deformable mirrors (MEMS DMs), which promise to reduce the size of the beam and overall instrument, a consideration that becomes very important for small telescopes. We describe our lab efforts and results, which include: the operation of our new active thermal control system; the demonstration of 5.4×10^{-8} (at time of this writing) average raw contrast in a dark zone from 2.0 - 5.2 λ /D in monochromatic light with a refractive PIAA system; preliminary results with an innovative low-cost set of reflective PIAA from JPL; preliminary results with a set of next-generation reflective PIAA built by Tinsley and designed to have the best theoretical broadband performance so far; and finally, an innovative design for a chromatically compensated focal plane occulter that promises to enhance broadband performance by matching the wavelength-dependent inner working angle of coronagraphs such as PIAA.

254.08

Status of the James Webb Space Telescope

Mark Clampin¹, C. Bowers¹

¹NASA's GSFC.

Exhibit Hall

The James Webb Space Telescope (JWST) is a large aperture (6.5 meter), cryogenic space telescope with a suite of near and mid-infrared instruments covering the wavelength range of 0.6 μ m to 28 μ m. JWST's primary science goal is to detect and characterize the first galaxies. It will also study the assembly of galaxies, star formation, and the formation of evolution of planetary systems. Recent progress in hardware development for the observatory will be presented, including a discussion of the status of JWST's optical system and recent flight mirror deliveries, progress with sunshield development, and the optical testing plan for the observatory. We also review the expected scientific performance of the observatory based on model predictions generated for the Observatory's successful Critical Design Review. We will also review the current integration and test schedule.

254.09

NuSTAR Galactic Science Plan

Victoria M. Kaspi¹, NuSTAR Team ¹*McGill Univ., Canada*.

Exhibit Hall

The Nuclear Spectroscopic Telescope Array (NuSTAR), scheduled for launch in February 2012, will allow for sensitive studies of high energy sources in the Milky Way Galaxy at an unprecedented depth in the 5-

80 keV range. The baseline 2-year mission includes a mixture of field surveys and targeted observations of known sources. Several months will be spent mapping Galactic fields, both near the Galactic center and towards the Norma arm. These surveys should identify large numbers of X-ray binaries, compact stellar remnants, as well as observe diffuse high energy emission. Targeted observations include studies of high energy emission from magnetars, local supernovae and supernova remnants, pulsars, and pulsar wind nebulae.

254.10

FORTIS: A Rocket-Borne Far-UV Spectro-Telescope

Brian Fleming¹, S. R. McCandliss¹, M. E. Kaiser¹, J. Kruk¹, P. D. Feldman¹, A. S. Kutyrev², S. H. Moseley² ¹Johns Hopkins University, ²NASA/GSFC.

Exhibit Hall

The Far-Ultraviolet Off-Rowland Telescope for Imaging and Spectroscopy (FORTIS) is a rocket-borne spectro-telescope designed to investigate Lyman alpha (Lya) escape from nearby star-forming galaxies and to quantify its relationship to the local gas-to-dust ratio. By operating in the 900 - 1700 Angstrom bandpass and incorporating a GSFC microshutter array at the prime focus, the FORTIS instrument enables simultaneous observations of both Lya and the far-UV continuum of the brightest HII regions of low redshift starforming galaxies. Ancillary ground-based optical spectroscopy of the target will provide the necessary Balmer line measurements to calculate the Lya escape fractions (Fleming et al. 2010). We present the optical design and capabilities of the FORTIS instrument, the first flight of which is currently scheduled for April of 2011 to observe the galaxy cluster Abell 1367.

254.11

Soft X-ray Polarimetry Laboratory Results

Herman L. Marshall¹, K. D. Murphy², N. S. Schulz¹, R. K. Heilmann¹, K. Jenks¹

¹MIT, ²Skidmore.

Exhibit Hall

We developed an instrument design capable of measuring linear X-ray polarization over a broad-band using conventional spectroscopic optics, using a method previously described by Marshall (2008) involving laterally graded, multilayer-coated flat mirrors. We present possible science investigations with such an instrument and two possible configurations. This instrument could be used in a small orbiting mission or scaled up for the International X-ray Observatory. We will present progress on laboratory work to demonstrate the capabilities of key components.

This work has been supported in part under a MIT Kavli Institute instrumentation development grant.

254.12

ACCESS: Mission Overview, Fabrication Status, and Preliminary Performance

Mary Elizabeth Kaiser¹, S. R. McCandliss¹, D. J. Sahnow¹, W. V. Dixon¹, P. D. Feldman¹, B. W. Gaither¹, H. W. Moos¹, R. S. Pelton¹, A. G. Riess¹, B. J. Rauscher², R. A. Kimble², J. W. Kruk², D. J. Benford², J. P. Gardner², R. J. Hill², D. M. Kahle², D. B. Mott², A. Waczynski², Y. Wen², B. E. Woodgate², R. C. Bohlin³, S. E. Deustua³, R. Kurucz⁴, M. Lampton⁵, S. Perlmutter⁶, E. L. Wright⁷

¹Johns Hopkins University, ²NASA Goddard Space Flight Center, ³Space Telescope Science Institute, ⁴Harvard Smithsonian Center for Astrophysics, ⁵Space Sciences Laboratory, ⁶University of California, Berkeley, ⁷University of California, Los Angeles.

Exhibit Hall

Improvements in the precision of the astrophysical flux scale are needed to answer fundamental scientific questions ranging from cosmology to stellar physics. ACCESS - Absolute Color Calibration Experiment for Standard Stars (Kaiser et al., 2009) is a sub-orbital program with a rocket-borne payload that will enable the transfer of absolute laboratory detector standards from NIST to a network of stellar

standards with a calibration accuracy of 1% and a spectral resolving power of R = 500 across the 0.35-1.7 micron bandpass. The ACCESS flight detector has been selected and initial tests have been performed. The detector flight electronics are being fabricated. The optical system fabrication is in progress. The ground calibration system fabrication and component testing has begun. The cornerstone of the ground calibration system is the artificial star system that will be used to transfer the NIST photodiode detector standards to the telescope payload and hence the stars. First flight is anticipated for late 2011 from White Sands Missile Range. We will present the instrument overview, status of the instrument fabrication, and the calibration and observation strategy. Support for this work was provided by NASA through grant NNX08AI65G and DOE through grant DE-FG02-07ER41506.

254.13

NuSTAR Extragalactic Science Plan

Kristin Madsen¹, NuSTAR Team

¹Caltech.

Exhibit Hall

The Nuclear Spectroscopic Telescope Array (NuSTAR), scheduled for launch in February 2012, will open the high energy extragalactic sky in the 5 - 80 keV band to sensitive study for the first time. The baseline 2-year mission includes a mixture of field surveys and targeted observations of known sources. A deep, several-month campaign observing the COSMOS and GOODS fields will significantly enhance our understanding of the sources contributing to the X-ray background at its 30 keV peak. In particular, models predict a population of heavily-obscured AGN, undetected in the soft X-rays, that will be seen in the hard X-ray observations of NuSTAR. Targeted observations include high energy studies of galaxy clusters to constrain non-thermal X-ray emission, coordinated blazar monitoring campaigns, observations of local starburst galaxies, and detailed studies of well-known AGN in order to study the physics of their high energy emission.

254.14

Charge Transfer Inefficiency Over The History Of The ACS WFC Instrument Of The HST

Brian A. Ferguson¹, L. Smith¹, N. Grogin¹, D. Golimowski¹

¹Space Telescope Science Institute.

Exhibit Hall

We have examined multiple epochs of data extending from April 2002, up through June 2010, from the Hubble Space Telescope's (HST) Advanced Camera for Surveys (ACS) Wide Field Channel (WFC), in effort to determine the charge transfer efficiency loss, (also known as charge transfer inefficiency: CTI), during the time this instrument has spent on-orbit. With special attention paid to the calibration data of the post Servicing Mission 4 (SM4) period, and in lieu of the gross abundance of calibration darks taken throughout the history of the ACS WFC, there existed a large and conclusive database of information as to the development of these notorious trails arising from CTI. The CTI trails extend from warm pixels much the same, and as reproducibly predictable, as the bleeding flux from point sources, with which we are all unfortunately so well acquainted. The growth and evolution of these trails, that proceed from, and downstream to, these recurrent warm pixels, has grown in a nonlinear fashion in both magnitude and shape relative to time elapsed on-orbit. We present an archive of CTI trails found throughout eight and a half years of ACS WFC orbit time, along with the chronological trends found therein.

Space Instrument Optimization by Implementing of Generic Three Bodies Circular Restricted Problem Cyrus Nejat¹

¹University of Southern California.

Exhibit Hall

In this study, the main discussion emphasizes on the spacecraft operation with a concentration on stationary points in space. To achieve these objectives, the circular restricted problem was solved for selected approaches. The equations of motion of three body restricted problem was demonstrated to apply in cases other than Lagrange's (1736-1813 A.D.) achievements, by means of the purposed CN (Cyrus Nejat) theorem along with appropriate comments. In addition to five Lagrange, two other points, CN1 and CN2 were found to be in unstable equilibrium points in a very large distance respect to Lagrange points, but stable at infinity. A very interesting simulation of Milky Way Galaxy and Andromeda Galaxy were created to find the Lagrange points, CN points (Cyrus Nejat Points), and CN lines (Cyrus Nejat Lines). The equations of motion were rearranged such a way that the transfer trajectory would be conical, by means of decoupling concept. The main objective was to make a halo orbit transfer about CN lines. The author purposes therefore that all of the corresponding sizing design that they must be developed by optimization techniques would be considered in future approaches. The optimization techniques to search for the most ideal response of a system.

254.16

WFPC2 Filters after 16 Years on Orbit

Pey Lian Lim¹, M. Quijada², S. Baggett¹, J. Biretta¹, J. MacKenty¹, R. Boucarut², S. Rice², J. del Hoyo³ ¹Space Telescope Science Institute, ²Goddard Space Flight Center, ³University of Arizona. Exhibit Hall

Wide Field Planetary Camera 2 (WFPC2) was installed on Hubble Space Telescope (HST) in December 1993 during Servicing Mission 1 by the crew of Shuttle Mission STS-61. WFPC2 replaced Wide Field Planetary Camera 1 (WFPC1), providing improved UV performance, more advanced detectors, better contamination control, and its own corrective optics. After 16 years of exceptional service, WFPC2 was retired in May 2009 during Servicing Mission 4, when it was removed from HST in order to allow for the installation of Wide Field Camera 3 (WFC3).

WFPC2 was carried back to Earth in the shuttle bay by the crew of Shuttle Mission STS-125. In a joint investigation by Goddard Space Flight Center (GSFC) and Space Telescope Science Institute (STScI), the Selectable Optical Filter Assembly (SOFA) of WFPC2 was extracted and the filter wheels removed and examined for any on-orbit changes. The filters were inspected, photographed and scanned with a spectrophotometer at GSFC. The data have been analyzed at STScI with a view towards understanding how prolonged exposure to the HST space environment affected the filters and what the resultant impacts are to WFPC2 calibrations.

We will summarize our results from these post-SM4 laboratory studies, including a comparison of preto post-mission filter throughput measurements, evaluations of the UV filter red leaks, and assessment of the condition of the filter coatings.

254.17

Observing scenarios for JWST's Near-Infrared Spectrograph

David R. Soderblom¹, T. Beck¹, W. Blair¹, D. Karakla¹, T. Keyes¹, J. Muzerolle¹, J. Tumlinson¹, J. Valenti¹ ¹STScl.

Exhibit Hall

The Near-Infrared Spectrograph (NIRSpec) on the James Webb Space Telescope will provide a new level of spectroscopic capability to address astrophysical problems. At this time the operating scheme for

NIRSpec is being designed, and to ensure that that scheme can support the full range of potential NIRSpec science a number of observing scenarios have been constructed. These scenarios are intended to conceptually exercise all of NIRSpec's operating modes for a broad range of potential observing conditions. These scenarios have enabled us to identify potential improvements to the ways in which NIRSpec is operated and to understand better the likely needs of the observing community. This poster will summarize the scenarios as well as describe the process we used and some of our conclusions.

254.18

Reducing the Read Noise of H2RG detector arrays: Eliminating Correlated Noise with Efficient Use of Reference Signals

Bernard J. Rauscher¹, R. G. Arendt², D. J. Fixsen³, D. Lindler⁴, M. Loose⁵, S. H. Moseley¹ ¹NASA's GSFC, ²CRESST/UMBC/GSFC, ³CRESST/UMd/GSFC, ⁴Sigma Space Corporation/GSFC, ⁵Markury Scientific, Inc..

Exhibit Hall

We present a process for characterizing the correlation properties of the noise in large two-dimensional detector arrays, and describe an efficient process for its removal. In the case of the 2k × 2k HAWAII-2RG detectors (H2RG) detectors from Teledyne which are being used on the Near Infrared Spectrograph (NIRSpec) on the James Webb Space Telescope (JWST), we find that we can reduce the read noise by thirty percent. Noise on large spatial scales is dramatically reduced. With this relatively simple process, we provide a performance improvement that is equivalent to a significant increase in telescope collecting area for high resolution spectroscopy with NIRSpec.

254.19

High Quantum Efficiency Photon-Counting Imaging Detector Development for UV (50-320 nm) Astronomical Observations

Timothy Norton¹, C. Joseph², B. E. Woodgate¹, J. Stock¹, G. M. Hilton¹, K. Bertness³ ¹NASA Goddard Space Flight Center, ²Rutgers University, Dept of Physics and Astronomy, ³NIST. Exhibit Hall

We are currently developing a high-quantum efficiency > 70% (peak), opaque photocathode-based, 2K x 2K pixel, zero-read-noise photon-counting detector system with the goal of enabling the highest possible sensitivity for space-based observations of ultra-faint astronomical targets in the UV.Current missions in the UV, eg HST (COS, STIS), GALEX etc although highly successful, exhibit relatively low quantum efficiency, < 40 % at Ly-a and < 10% in the NUV between 150 and 320 nm.Recent improvements in UV photocathodes using cesiated p-doped GaN, by GSFC and others have obtained QEs of up to 70% at 121 nm and ~50% at 180 nm, (a factor 3 - 5 better than the traditional CsI and CsTe based systems) and so are the best hope for sensitivity improvements over most of the FUV and NUV spectral range for new medium and long term missions. However, these QEs are obtained on opaque planar and nanowire photocathodes, and have not been demonstrated in microchannel plate based detectors. The only known way to use these improved photocathodes while maintaining the high QE is to use them in electron-bombarded CCD or CMOS configurations. The detector concept under investigation is based on an opaque (GaN, KBr) photocathode, magnetically focused to a back-thinned CMOS readout stage. We are currently incorporating a QE optimized KBr photocathode deposited on a stainless steel substrate with an Intevac Inc, ISIE11 EBCMOS sensor into a demountable, magnetically focused detector system, designed and built at Rutgers University, NJ in order to demonstrate high quantum efficiency photon-counting imaging performance in the FUV region. We report here progress on integration and evaluate of the system for quantum efficiency, imaging performance, photo-electron counting efficiency and dark count.

254.20 A Library of Simulated Cosmic Rays Impacting JWST HgCdTe and SiAs detectors Massimo Robberto^{\rm 1}

¹STScI.

Exhibit Hall

I present a library of simulated cosmic ray events on JWST HgCdTe and SiAs detectors. The cosmic rays are calculated for different levels of solar activity, taking into account the relative frequency of the most abundant nucleons (H, He, C, N, O, Fe) and their energy. A shielding of 100mil Al equivalent thickness is assumed. The cosmic rays are traced through the detector material assuming they impact a random point within a pixel and are isotropically distributed. The energy losses are calculated using state of the art modeling for the different detector material, taking into account the different stoichiometric ratios and density for HgCdTe of different cutoff wavelengths and assuming optimal detector thickness. The effect of interpixel capacitance is finally added to the charges generated by the cosmic rays through convolution with a coupling filter function.

254.21

Standard stars observed with the Infrared Spectrograph on the Spitzer Space Telescope

Gregory C. Sloan¹, D. A. Ludovici², H. W. W. Spoon¹, V. Lebouteiller³, J. Bernard-Salas⁴, D. J. Barry¹ ¹Cornell Univ., ²West Virginia Univ., ³SAp/CEA Saclay, France, ⁴IAS Paris, France. Exhibit Hall

The Infrared Spectrograph (IRS) on the Spitzer Space Telescope observed a large suite of potential standard stars during the cryogenic phase of the Spitzer mission. We present spectral templates for those standards observed most frequently and use those templates to produce calibrated spectra of the remaining standards. We discuss the overall photometric calibration in the mid to far infrared, comparing observations with the IRS Red Peak-Up array, the MIPS 24-um array, the IRAS Faint-Source Catalog (FSC), and the Midcourse Space Experiment (MSX). An examination of the SiO band at 8 um in K giants reveals the difficulty of predicting its strength, and an examination at longer wavelengths reveals the importance of the OH band structure in K giants, which must be addressed if the spectrophotometric calibration is to be better than 1.5%. We also examine what the long-wavelength behavior of the spectra can tell us about the suitability of Planck functions, Engelke functions, and model spectra to estimate the overall shape of the spectra.

254.22

Characterization and Calibration of the Infrared Spectrograph on the Spitzer Space Telescope

Dominic Ludovici¹, G. C. Sloan², D. J. Barry², V. Lebouteiller³, J. Bernard-Salas⁴, H. W. W. Spoon² ¹West Virginia University; Cornell University, ²Cornell University, ³SAp/CEA Saclay, France, ⁴IAS Paris, France.

Exhibit Hall

Throughout the 5.7-year period when the Spitzer Space Telescope operated at cryogenic temperatures, the Infrared Spectrograph (IRS) repeatedly observed a small set of standard stars. For a subset of the standards, the spectroscopic observations were supplemented with photometry at 22 um from the Red Peak-Up array in the Short-Low (SL) module. This subset included the K giants HR 6348, HD 166780 and HD 173511, and the A dwarfs alpha Lac and delta UMi. Analysis of the peak-up photometry reveals small temporal changes in sensitivity which require adjustments for precise photometry. In addition, the data show subtle non-linearities, with a change in sensitivity of roughly 2% over an order of magnitude in flux density. The narrow slit in the SL module makes it susceptible to pointing-induced errors in the apparent brightness of a source, because a slight shift in pointing changes the fraction of the point-spread function (PSF) truncated by the slit edges. An investigation of repeated spectroscopy of the standard

stars reveals that multiplicative corrections for these pointing-induced throughput errors are valid in most cases. Only when 15% or more of the flux from a source is lost do the changes in the slope exceed 2%. We have also used the repeated observations of the standards to construct spectral templates for them which can be used as truth spectra for calibration. Most of the standards are well behaved, with the exception of alpha Lac, which deviates from a Rayleigh-Jeans tail at the longest wavelengths by a few percent. This possible excess may indicate the presence of a cool debris disk.

254.23

JWST Absolute Flux Calibration Planning

Karl D. Gordon¹, R. Bohlin¹

¹Space Telescope Science Institute. Exhibit Hall

The planning for the absolute flux calibration of all four JWST science instruments will be described. The main goal is to provide a uniform calibration (photometric and spectrophotometric) across all instruments using a common set of calibration stars. These stars will include white dwarfs, AOV, and solar type stars. The combination of these different types of stars will serve to check for systematic biases in the calibration as well as tie the Hubble (based on white dwarfs) and Spitzer (based on AOV and solar type stars) calibrations to the JWST calibration. An initial set of calibrators has been investigated and how they map to the sensitivity ranges of the JWST instruments will be detailed. Further work will concentrate on expanding the sample to more fully map the JWST instrument sensitivities and vetting individual calibration stars.

254.24

Dithering Observations with JWST's NIRCam

Jay Anderson¹ ¹STScl.

Exhibit Hall

Preparations for planning observations with JWST are already well underway at STScI. Many of the aspects of HST observation planning will carry over to JWST, but some things will be different. With HST, users are able to define arbitrary dither patterns (or use no dithering at all) in their Phase-2 submissions. This has allowed many observers to optimize their data quality for the particular science they are focused on. But, unfortunately, when the data reach the archive, the images are often less valuable to the community than they could be, either because of a lack of good dithering or because the association-based pipeline is not optimized for the particular dither pattern used. JWST will do things differently. Except in rare circumstances, such as planetary-transit observations, JWST users will be forced to dither, and they will have a limited set of dithering options to choose from. The NIRCam teams at STScI and UAz have designed a set of dither patterns that are flexible enough to meet the various anticipated science objectives, but they will also be homogeneous enough that the archive and association products will be of uniformly high quality.

254.25

The Nuclear Spectroscopic Telescope Array (NuSTAR)

Fiona Harrison¹, S. Boggs², F. Christensen³, W. Craig⁴, C. Hailey⁵, W. Zhang⁶, NuSTAR Team ¹Caltech, ²UC Berkeley, ³Danish Technical University Space Center, Denmark, ⁴UC Berkeley/LLNL, ⁵Columbia University, ⁶GSFC.

Exhibit Hall

The Nuclear Spectroscopic Telescope Array (NuSTAR) is a NASA Small Explorer (SMEX) mission scheduled for launch in February 2012. NuSTAR will be the first focusing high energy satellite sensitive in the hard X-ray band, and will probe the X-ray sky approximately two orders of magnitude more sensitively than

currently achievable. NuSTAR will answer fundamental questions about the Universe: How are black holes distributed through the cosmos, and what is their contribution to the cosmic X-ray background? How were the heavy elements forged in the explosions of massive stars? What powers the relativistic jets in the most extreme active galaxies? This poster discusses the NuSTAR design, performance and current status; accompanying posters discuss the baseline two-year science program.

254.26

Making Telescopes For NASA Explorer Missions: Credible Paradigms and The Wise Example Anthony B. Hull¹, M. Schwalm²

¹L-3 Integrated Optical Systems: Tinsley, ²L-3 Integrated Optical Systems: SSG. Exhibit Hall

The ASTRO 2010 Decadal Survey emphasized that NASA priority should be given to Principal Investigator led Explorer competed missions. Since the percentage of a mission's resources available to telescope implementation must be only a fraction of the mission cap, it is timely to examine paradigms that are capable of yielding the maximum credible telescope for the intended mission. We will discuss an integrated product team approach which leverages on extensions from heritage hardware, references actual cost experience, and can produce sophisticated spaceborne telescopes under constraints of Explorer class missions. Lessons learned from the recent WISE telescope, implemented at L-3 Integrated Optical Systems (SSG, Tinsley, Brashear) are evoked. This approach is relevant to planetary and earth science missions, as well as to astrophysics missions.

254.27

Nirspec, The Near-ir Multi-object Spectrograph For Jwst

Peter Jakobsen¹, S. Arribas², T. Beck³, S. Birkmann¹, T. Boeker¹, A. Bunker⁴, S. Charlot⁵, G. De Marchi¹, P. Ferruit¹, M. Franx⁶, R. Maiolino⁷, H. Moseley⁸, J. Muzerolle³, B. Rauscher⁸, M. Regan³, H. Rix⁹, M. Sirianni¹, D. Soderblom³, J. Tumlinson³, J. Valenti³, C. Willott¹⁰

¹ESTEC, Netherlands, ²DAMIR, Spain, ³STScI, ⁴Oxford University, United Kingdom, ⁵IAP, France, ⁶Leiden University, Netherlands, ⁷INAF, Italy, ⁸NASA/GSFC, ⁹MPIA, Germany, ¹⁰Ottawa University, Canada. Exhibit Hall

NIRSpec will be the first slit-based astronomical multi-object spectrograph to fly in space, and is designed to provide spectra of faint objects over the near-infrared 1.0 - 5.0 micron wavelength range at spectral resolutions of R=100, R=1000 and R=2700. The instrument's all-reflective wide-field optics, together with its novel MEMS-based programmable micro-shutter array slit selection device and its large format low-noise HgCdTe detector arrays, combine to allow simultaneous observations of >100 objects within a 3.4 x 3.5 arcmin field of view with unprecedented sensitivity. A selectable 3 x 3 arcsec Integral Field Unit and five fixed slits are also available for detailed spectroscopic studies of single objects. NIRSpec is being built for the European Space Agency (ESA) by EADS Astrium as part of ESA's contribution to the JWST mission. The NIRSpec micro-shutter and detector arrays are provided by NASA/GSFC.

254.28

Extending HST/COS/G130M Coverage Down to 900Å with Two New Central Wavelengths.

Steven V. Penton¹, S. N. Osterman¹, S. Béland¹, C. Oliveira², D. Massa², N. Sami², P. Charles², A. Alessandra²

¹Univ. of Colorado, ²Space Telescope Science Institute.

Exhibit Hall

The far-ultraviolet (FUV) channel of the Cosmic Origins Spectrograph (COS) is designed to operate between 1130Å and 1850Å, limited at shorter wavelengths by the reflectivity of the MgF₂ protected aluminum reflective surfaces on the Hubble Space Telescopes' (HST) Optical Telescope Assembly (OTA)

and on the COS FUV diffraction gratings. However, because the detector for the FUV channel is windowless, it retains some sensitivity at shorter wavelengths due to the first surface reflection from the MgF₂ coated optics. On-orbit observations verified that the COS G140L/1230 mode was sensitive down to at least the Lyman limit with 10-20 cm² effective area between 912-1070Å, and rising rapidly to over 1000 cm² beyond 1150Å. Following this initial work we explored the possibility of using the G130M grating out of band to provide coverage down to 900Å.

We present on-orbit calibration results (wavelength solutions, spectral resolution, cross-dispersion profiles, sensitivity results, etc.) and supporting ray trace simulations for these two new observing HST/COS/G130M modes. These modes will be available in HST Cycle 19 as the new G130M central wavelength settings of 1055Å and 1096Å. These new modes provide effective areas twice that previously reported for the G140L ranging from ~20 cm² at 912 Å to ~30 cm² at 1070 Å then rapidly rising to 2000 cm² at > 1140 Å. Unlike the G140L modes, the new COS G130M modes are designed to place the FUV segment-B below the rapid increase in effective area so that targets bright at > 1140 Å can be observed by disabling the FUV segment-A.

254.29

Comparing Occulter Performance For Missions Of Different Scales

Eric Cady¹, S. Shaklan¹, D. Lisman¹, J. Kasdin², D. Spergel²

¹Jet Propulsion Lab, ²Princeton University.

Exhibit Hall

Occulters are a promising concept to enable direct detection of exoplanets from space: these are spacecraft with precisely-shaped optical edges which would fly in formation with a telescope, blocking light from a star while leaving light from nearby planets unaffected. Occulters can be designed by optimization for use with telescopes over a wide range of telescope aperture sizes, science bands, and starlight suppression levels, and it can be shown that this optimization depends primarily on a small number of nondimensional parameters. We show how these parameters may be used to relate and compare the performance of occulter-telescope systems of differing scales and bandpasses, and discuss some point designs applicable to current telescopes and telescope concepts. The telescopes in these systems have apertures ranging from less than a meter to greater than 10m; while these designs are all capable of detecting terrestrial planets in habitable zones of nearby stars, they may vary significantly in cost and expected science return.

254.30

Optimization of Broadband Wavefront Correction at the Princeton High Contrast Imaging Laboratory Tyler Dean Groff¹, N. Kasdin¹, A. Carlotti¹

¹Princeton University.

Exhibit Hall

Wavefront control for imaging of terrestrial planets using coronagraphic techniques requires improving the performance of the wavefront control techniques to expand the correction bandwidth and the size of the dark hole over which it is effective. At the Princeton High Contrast Imaging Laboratory we have focused on increasing the search area using two deformable mirrors (DMs) in series to achieve symmetric correction by correcting both amplitude and phase aberrations. Here we are concerned with increasing the bandwidth of light over which this correction is effective so we include a finite bandwidth into the optimization problem to generate a new stroke minimization algorithm. This allows us to minimize the actuator stroke on the DMs given contrast constraints at multiple wavelengths which define a window over which the dark hole will persist. This windowed stroke minimization algorithm is written in such a way that a weight may be applied to dictate the relative importance of the outer wavelengths to the central wavelength. In order to supply the estimates at multiple wavelengths a

functional relationship to a central estimation wavelength is formed. Computational overhead and new experimental results of this windowed stroke minimization algorithm are discussed. The tradeoff between symmetric correction and achievable bandwidth is compared to the observed contrast degradation with wavelength in the experimental results. This work is supported by NASA APRA Grant #NNX09AB96G. The author is also supported under an NESSF Fellowship.

254.31

Optimization Of The Efficiency Of A Pre And Post Apodized Piaa Coronagraph Using A Numerical Propagator.

Alexis Carlotti¹, L. Pueyo², N. J. Kasdin¹

¹Princeton University, ²Johns Hopkins University - STScI. Exhibit Hall

Using a numerical propagator based on the Huygens integral, we study the apodization profiles (and PSFs) provided by a set of two PIAA mirrors that follow a square geometry. This choice is made as deformable mirrors could potentially be used as pupil mappers. A pre-apodizer and a post-apodizer are needed to improve the contrast and relax the manufacturing constraints of the mirrors. The stroke, minimum radius of curvature and diameter of the mirrors altogether with the parameters that define the pre and post apodizers' properties are connected to the performances of the coronagraph in term of contrast, throughput and inner working angle. Characterizing these relations allows us to invert some of them. For example, we are able to set a specific value for the final throughput and to find out, for a particular mirror's diameter and stroke, the distance between the mirrors as well as the characteristics of the pre and post apodizers that need to be used. Contrast maps are given as functions of the stroke, the diameter, the radius of curvature and the throughput. All these numerical tools help us to understand the trade-offs that exist behind the design of a PIAA system. There is a direct relation between the diameter, stroke, maximum radius of curvature of the mirrors and the strength of the postapodizer. Increasing the diameter improves the contrast but asks for a higher stroke and bigger distance. For a given set of mirrors, a better contrast can then be obtained by strengthening the pre and post apodizers at the expense of the throughput and the inner working angle. The post-apodizer could either be a transmittive, continuous apodizer or a binary apodizer. The latter case is explored and optimized binary apodizers are found for several PIAA cases. This work is supported by a NASA APRA grant.

254.32

Interference-Based Coronagraphy for Speckle Identification

Elizabeth Jensen¹, A. Carlotti¹, N. J. Kasdin¹, M. Littman¹

¹*Princeton University.*

Exhibit Hall

Current observations in the context of exoplanet searches with coronagraphic instruments have shown that one of the main limitations to high-contrast imaging is due to residual quasi-static speckles. Speckles look like the image of a planet, therefore threatening the planet detection. But they have a different spectral behavior and are optically coherent with the star. This property lends itself to the use of interference to distinguish light speckles from the image of a planet. We analyze two approaches to address this identification problem. To create this device two techniques are considered. Both techniques use a shaped pupil paired with a focal plane mask (FPM) for the coronagraph. Light that passes by the FPM consists of speckles and planet light. Using the reflection from the metallic surface of the FPM, the starlight is redirected to create a flat "reference field". This reference field is then interfered with the speckle/planet light. Due to the coherence of the speckles with the reference field, as we change the phase of the interfering light we see an intensity change in the speckles. The parts of the image that is changing in intensity are now identified as the speckles and the light that is unchanged

from the phase sweep (incoherent light to the starlight) is a planet. This generic technique will work with any type of coronagraph, ground or space-based. However, we illustrate the results with simulations and lab data designed for space-based AO and coronagraphy.

254.33

Understanding and Using the Fermi Science Tools

Elizabeth C. Ferrara¹, Fermi Science Support Center

¹NASA/GSFC/CRESST.

Exhibit Hall

The Fermi Science Support Center (FSSC) provides information, documentation, and tools for the analysis of Fermi science data, including both the Large-Area Telescope (LAT) and the Gamma-ray Burst Monitor (GBM). Source and binary versions of the Fermi Science Tools can be downloaded from the FSSC website, and are supported on multiple platforms. An overview document, the Cicerone, provides details of the Fermi mission, the science instruments and their response functions, the science data preparation and analysis process, and interpretation of the results. Analysis Threads and a reference manual available on the FSSC website provide the user with step-by-step instructions for many different types of data analysis: point source analysis - generating maps, spectra, and light curves, pulsar timing analysis, source identification, and the use of python for scripting customized analysis chains. We present an overview of the structure of the Fermi science tools and documentation, and how to acquire them. We also provide examples of standard analyses, including tips and tricks for improving Fermi science analysis.

254.34

The Fermi Science Support Center

Donald J. Horner¹, Fermi Science Support Center

¹NASA's GSFC.

Exhibit Hall

The Fermi Science Support Center (FSSC) serves as the primary interface between the Fermi Gamma-ray Space Telescope mission and the scientific community. The FSSC supports the planning and scheduling of science observations and maintains an archive of all publicly accessible Fermi data. The FSSC also maintains and distributes data analysis software and associated documentation as well as providing technical and scientific support. In addition, the FSSC is administering the guest investigator program for NASA Headquarters and provides proposal preparation tools and documentation. We present an overview of the FSSC's role in each of these activities.

254.35

Fermi Science Support Center Data Servers and Archive

Thomas E. Stephens¹, Fermi Science Suport Center

¹Wyle IS/GSFC.

Exhibit Hall

The Fermi Science Support Center (FSSC) provides the scientific community with access to public Fermi data. Through its website the FSSC provides planning and scheduling products, such as long and short term observing timelines, spacecraft position and attitude histories, and exposure maps.

For scientific data from the Gamma-Ray Burst Monitor (GBM), the FSSC website links to NASA's High Energy Astrophysics Science Archive Research Center's (HEASARC) Browse interface, which provides a searchable interface to the GBM burst, trigger, and daily data archives. For example, all the GBM data products for bursts matching a given criteria can be packaged together and downloaded through Browse.

The photon and event data produced by the Large Area Telescope (LAT), Fermi's primary instrument, are

distributed through a custom FSSC interface. Users can request all photons detected from a region on the sky over a specified time and energy range.

We present an overview of the different data products provided by the FSSC and how they can be accessed.

254.36

WFC3: Spectroscopy and Operational Enhancements

John W. MacKenty¹, H. Bushouse¹, R. Gilliland¹, B. Hilbert¹, L. Petro¹, N. Pirzkal¹, A. Rajan¹, WFC3 Team ¹STScl.

Exhibit Hall

The Wide Field Camera 3 was installed into the Hubble Space Telescope in May 2009. Our presentation discusses the performance of the WFC3 near infrared slitless spectroscopy mode, improvements to the definition and use of detector subarrays, and recent experiments aimed at determining the limits of high contrast imaging. We also discuss the implementation status of a new mode to achieve very high signal to noise observations of bright sources in the infrared channel via controlled motion of the telescope. This offers the potential for high S/N photometry and spectroscopy of very bright targets with excellent time resolution.

254.37

WFC3 UVIS Detector: On-Orbit Performance

Tiffany M. Borders¹, S. Baggett¹, H. Bushouse¹, R. Gilliland¹, J. Kalirai¹, L. Petro¹, V. Kozhurina-Platais¹, J. MacKenty¹, K. Noeske¹, A. Rajan¹, WFC3 Team

¹STScI.

Exhibit Hall

Installed in the Hubble Space Telescope (HST) in May 2009, the Wide Field Camera 3 (WFC3) is performing extremely well on-orbit. The UVIS channel (200 to 1000 nm) contains a pair of e2v 4Kx2K CCDs, covering a 160x160 arcsec field of view at 0.04 arcsec/pixel. This report summarizes the performance of the WFC3 UVIS detector, including primary characteristics such as read noise, dark current levels, hysteresis prevention, and photometric stability. We also present ongoing studies of the evolution of the detector including the effects of radiation damage on the charge transfer efficiency (CTE) of the CCDs and strategies for mitigating those CTE losses.

254.38

Wide-Field Camera 3 Data Analysis

Howard A. Bushouse¹, M. Dulude¹, B. Hilbert¹, J. MacKenty¹, L. Petro¹, N. Pirzkal¹, WFC3 Team ¹STScl.

Exhibit Hall

The Wide-Field Camera 3 (WFC3) on HST has two channels, one in the UV-optical range and one in the near-IR, that are producing excellent imaging results. Here we review some of the features that observers can encounter in their data, some due to detector and instrumental artifacts and others due to the space-based environment of HST. This includes the nature of the near-IR background seen by HST/WFC3, scattered Earth light, optical ghosts, and isolated regions of reduced sensitivity in the IR field of view ("blobs"). We review processes by which some of these can either be avoided to begin with or mitigated in the data reduction and analysis process. This includes the appropriate use of the data quality flags that are included in the calibrated WFC3 imaging products.

254.39 WFC3 UVIS and IR Flat Fields

Cheryl M. Pavlovsky¹, S. Baggett¹, T. Borders¹, H. Bushouse¹, T. Dahlen¹, M. Dulude¹, B. Hilbert¹, J. Kalirai¹, V. Kozhurina-Platais¹, J. Mack¹, J. MacKenty¹, N. Pirzkal¹, A. Rajan¹, E. Sabbi¹, A. Viana¹, WFC3 Team

¹STScl.

Exhibit Hall

The WFC3 flat field program for both the UVIS and IR channels consists of ground flats, LP flats, sky flats and earth flats. Creation of the WFC3 LP flats starts with the ground flats (pixel-to-pixel variation) and are combined with on-orbit observations of stellar fields (low frequency modulation). The ground flat field accuracy is +/-3% peak-to-peak for the IR and 1.5 to 4.5% in the UVIS. Assessment of the flats is done by identifying the peak-to-peak and RMS variations. As we continue to refine these flats and test them for inclusion in CDBS and the WFC3 pipeline we are in parallel executing both a sky flats and an earth flats program to use as secondary confirmation of the flat field program. In addition, internal flats are used to monitor flat field stability.

254.40

Characterization of the HST Wide Field Camera-3 Image Distortion

Larry D. Petro¹, V. Kozhurina-Platais¹, M. Dulude¹, C. Cox¹, J. Mack¹, WFC3 Team ¹STScl.

Exhibit Hall

Images formed by the WFC3 IR and UVIS channels are distorted from a tangent plane projection of the sky by of order 10%. General fourth order polynomials adequately represent the distortion field of each channel. For WFC3, we calibrate the coefficients of the polynomials from the measured positions of stars in images of the globular cluster omega Cen and astrometric catalogs of their positions. Such polynomials obtain 0.1-pixel accuracy, which is sufficient for the MultiDrizzle PyRAF task to combine mosaics of exposures, to reject cosmic rays artifacts, and to co-add dithered images. Refractive elements (optical filters, windows, and correctors) perturb the distortion field, which may be represented by filter-dependent polynomials, and the filter dependence of the variation of 10 of the UVIS-filter polynomials and 5 of the IR-filter polynomials, and the filter dependence of the variation of the distortion field. Images formed by the HST Optical Telescope Assembly suffer variations due to changes in temperature during an orbit. We present measurements of the orbital and secular variation of the image scale and skew caused by that variation. The stated accuracy of the calibrations is verified by the comparison of pairs of rectified images taken through different filters, at different pointings, and at different telescope orientations.

254.41

WFC3 IR detector: On-Orbit Performance

Bryan Hilbert¹, K. Long¹, A. Riess¹, S. Deustua¹, H. Bushouse¹, J. Kalirai¹, A. Rajan¹, M. Dulude¹, WFC3 Team

¹STScI.

Exhibit Hall

In the 20 months since Wide Field Camera 3 (WFC3) was installed in the Hubble Space Telescope (HST), the WFC3 team has collected and analyzed a large amount of calibration data. We describe the current status of several IR channel characterization and calibration efforts, including persistence and count-based and count rate-based non-linearity (a.k.a reciprocity failure, or the Bohlin effect). We also summarize the photometric performance of the IR channel, focusing on zeropoints and stability.

254.42 The Gravity and Extreme Magnetism Small Expolorer Mission Timothy R. Kallman¹, J. Swank¹, K. Jahoda¹, GEMS Team

¹NASA's GSFC.

Exhibit Hall

Polarization is an inherently geometric quantity and provides information on source geometry inaccessible via spectroscopy or timing. To date, there have been reliable detections of X-ray polarization from only one object outside the solar system (the Crab nebula). Recent development of photoelectric polarimetry makes it possible to perform sensitive X-ray polarimetry with a modest mission. GEMS was recently selected by NASA to be the 13th Small Explorer mission with launch planned for 2014. GEMS will be ~100× more sensitive than any previously flown X-ray polarimeter and should provide useful polarization measurements for dozens of sources, to lower than predicted levels. GEMS will lead to new insights into the nature of accreting black holes, highly magnetized neutron stars, and supernova remnants.

255

Exploring the Far-IR/Sub-mm with the Herschel Space Observatory **Poster Session** Exhibit Hall

255.01

Herschel's DEBRIS - An Update on the Search for Kuiper Belts Around the Nearest Stars Harold M. Butner¹, B. Matthews², DEBRIS Survey Team

¹James Madison Univ., ²NRC-Herzberg Institute for Astrophysics, Canada. Exhibit Hall

DEBRIS (Disk Emission via a Bias-free Reconnaissance in the Infrared/Submillimetre) is an open time key project on Herschel that aims to conduct an unbiased statistical survey for debris disks around the nearest stars. The goal is to achieve flux-limited observations at 100 and 160 microns - and thereby reach unprecedented debris disk mass limits. The sample includes 446 primaries, 348 of which are observed by the DEBRIS team and 98 which are covered by another project (DUNES - DUst disks around NEarby Stars). The sample covers spectral types from A0 through M7, and is designed to allow the detection of dust masses similar to those of our own Kuiper belt. The superior resolution of Herschel combined with the fact that our sample are all nearby stars will provide resolved disks for many of the detected disks. We will discuss the status of ongoing Herschel observations for this unique unbiased survey of debris disk candidates.

255.02

Herschel DUNES Observations of Cold Debris Disks Around Nearby Stars

Aki Roberge¹, C. Eiroa², DUNES Team

¹NASA GSFC, ²Universidad Autonoma de Madrid, Spain. Exhibit Hall

The DUNES (DUst discs around NEarby Stars) Open Time Key Programme for the Herschel Space Observatory is a sensitivity-limited photometric survey for faint, cold debris disks around nearby FGK stars. It takes advantage of the PACS and SPIRE instruments to detect and characterize cold disks as faint as $L_{dust}/L_{star} \sim 10^{-7} - 10^{-6}$, at dust temperatures around 30 - 40 K. Such systems are extrasolar analogues of Solar System's Edgeworth-Kuiper Belt (EKB). DUNES will observe a statistically significant, volumelimited (d < 20 pc) sample, constrained only by background confusion. Stars at larger distances (d < 25 pc) with previously known exoplanets and/or Spitzer-detected faint debris disks are also included. More than one third of the DUNES sample has been observed to date. Our goal of detecting very faint,

cold dust disks has been achieved; many disks are also spatially resolved. The unresolved disks show a variety of spectral energy distributions, some suggesting the presence of cold EKB-like dust rings. A number of previously unknown debris disks have been detected, including the coldest disks yet found. Preliminary results relating disk properties to the host star parameters will be shown.

255.03

Very Early Phases of Massive Star Formation: An SMA Follow-up of Herschel Hi-Gal Survey Cores Howard Alan Smith¹, Q. Zhang¹, I. M. Jimenez-Serra¹, M. Beltran², R. Cesaroni³, S. Finn⁴, J. Foster⁴, J. Jackson⁴, S. Molinari⁵, S. Viti⁶

¹Harvard-Smithsonian, CfA, ²Universitat de Barcelona, Spain, ³INAF-Osservatorio di Arcetri, Italy, ⁴Boston University, ⁵INAF-IFSI, Italy, ⁶UCL, United Kingdom.

Exhibit Hall

We used the Submillimeter Array (SMA) to observe eight cold, massive (~1000Msol) dense cores in dark clouds discovered in the Herschel HiGal survey. In contrast to numerous studies of hot molecular cores, very little is known about objects prior to the hot core phase. The SMA results allow us to study systematically the physical and chemical evolution of these dense cores. These protostellar objects were selected because the Hershel SEDs of the dust have temperatures spanning the range between about 10K and 20K, suggestive of different evolutionary phases of very young stars, because the objects were comparatively bright at 250 microns (~ 10Jy) and distinct in all five FIR HiGal bands, and because they seemed to be morphologically simple. Only one of the sources is bright enough to be detected at MIPS24; this source, the most mature one, already shows a small outflow in CO. The SMA was used in both compact and very extended configurations, with the 230GHz band. The SMA molecular line maps will be compared with chemical modelling (including dust grain and gas phase reactions) to constrain the physical conditions in these young cores, and their evolutionary stages.

255.04

Herschel PACS Spectroscopy of Spitzer identified Protostars in the Orion Molecular Clouds

Manoj Puravankara¹, D. M. Watson¹, D. Neufeld², R. Vavrek³, T. Megeath⁴, W. J. Fischer⁴, B. Ali⁵, HOPS team

¹University of Rochester, ²Johns Hopkins University, ³HSC ESAC, Spain, ⁴University of Toledo, ⁵NHSC, IPAC, Caltech.

Exhibit Hall

We present Herschel PACS spectra of Spitzer identified protostars in the Orion molecular clouds, obtained as part of the Herschel Orion Protostar Survey (HOPS). HOPS is a 200-hour Herschel open-time key program which will obtain PACS photometry at 70 and 160 microns for 286 protostars and PACS spectra from 55 to 210 microns for 36 protostars. We will use the Spitzer IRAC/MIPS and PACS photometry and SED modeling to characterize the envelope and disk properties and the evolutionary states of the Orion protostars. The spatial distribution and excitation states of the fine structure lines such as [OI] and [CII] and molecular lines such as H2O, OH and CO in the PACS spectra will be used to study the physical conditions and heating mechanisms in the envelopes and outflows in protostars. Complementing the PACS spectra with high resolution Spitzer IRS spectra, we will measure various flow rates in these protostellar systems and study the jet/outflow feedback onto the surrounding molecular material.

HerMES: Herschel Observations of Cirrus in the Extragalactic First-Look Survey Field David L. Shupe¹, G. Lagache², HerMES Team

¹NASA Herschel Science Center, Caltech, ²Institut d'Astrophysique Spatiale, France. Exhibit Hall

The extended submillimeter emission is studied from Herschel observations of the extragalactic First-Look Survey field, made with the 250, 350 and 500 µm channels of the Spectral and Photometric Imaging Receiver (SPIRE) instrument as part of the Herschel Multi-tiered Extragalactic Survey (HerMES). The analysis divides into two parts. First, the Herschel maps and the IRAS 100 µm map are low-pass-filtered and smoothed to the 10 arcminute resolution of the HI map of Lockman & Condon (2006). The infrared maps are used to determine dust temperature and emissivity, for components of the cirrus that are clearly identified in the HI map. The infrared emission per H-atom is compared to ISM models. The second part of the analysis exploits the relatively high spatial resolution of the Herschel-SPIRE data to search for variations in the color of the dust emission within individual cirrus components. This work is based on observations made with Herschel, a European Space Agency Cornerstone Mission with significant participation by NASA. Support for this work was provided by NASA through an award issued by JPL/Caltech.

255.06

HIGGS: The Herschel Inner Galaxy Gas Survey, First Results

Christopher L. Martin¹, HIGGS Team

¹Oberlin College.

Exhibit Hall

The Herschel Inner Galaxy Gas Survey (HIGGS) is a Herschel Key Project to use the HIFI and PACS instruments to observe [CII], [NII], [OI], [OIII], and high-J CO emission lines in focused regions near the Galactic Center. By separating and evaluating the distinctly different roles of the central nuclear engine, the Galactic Bar, and dynamical stellar and interstellar feedback mechanisms, HIGGS will provide a high-resolution template for the physical processes in galactic nuclei throughout the local universe, in particular those engaged in starburst activity.

In September, we collected our first Herschel spectra and our early analysis shows this region to be even more fascinating than we had anticipated. We look forward to sharing our excitement with the broader astronomical community.

255.07

Improving Herschel HIFI HEB Baseline Reduction

Leanne Sherry¹, K. Tchernyshyov¹, C. L. Martin¹

¹Oberlin College.

Exhibit Hall

Bands 6 and 7 of Herschel's HIFI instrument suffer from a phase and amplitude shifting ripple that is dependent upon numerous receiver parameters. While one can attempt to fit a sinusoid to the ripple, this quickly becomes insufficient for a desirable signal to noise ratio. Extending upon a technique pioneered by Ronan Higgins, we have come up with a faster, more comprehensive way to reduce HEB baselines. We will demonstrate this technique using the data of the Herschel Inner Galaxy Gas Survey (HIGGS) project.

Photoelectric Heating And The Physical Conditions Of The ISM: Observations Of NGC 4559 With The Herschel/PACS Spectrometer

Kevin V. Croxall¹, J. D. T. Smith¹, P. N. Appleton², L. Armus³, P. Beirão³, A. D. Bolatto⁴, D. A. Dale⁵, E. J. Murphy³, M. G. Wolfire⁴, KINGFISH Team

¹University of Toledo, ²NASA Herschel Science Center, ³Spitzer Science Center, ⁴University of Maryland, ⁵University of Wyoming.

Exhibit Hall

The cooling of the neutral interstellar medium in galaxies is dominated by far-infrared line emission. This emission is characterized by features which reveal the physical conditions of the phases of the ISM as well as indicate the source of the heating. Despite many efforts, studies of heating and cooling via infrared line emission were hampered by a lack of spatial resolution. However, the recently launched Herschel and Spitzer space telescopes enable us to spatially map emission from mid- and far-infrared lines in nearby galaxies rather than adopting global values. We highlight early results from the KINGFISH spectroscopic program which is mapping strong cooling lines in several nearby galaxies using the Herschel Space Observatory. These observations are complemented by Spitzer/SINGS 5-35 μ m data to permit a full census of line and dust emission. In particular we focus on emission from resolved regions of NGC 4559, a nearby late type spiral galaxy that was part of the KINGFISH science demonstration program. Line diagnostics of most regions of emmision are consistent with predictions PDR models. Nevertheless, we have detected an excess of [C II] 157 μ m emission from the diffuse portions of NGC 4559's disk. Based on observations obtained with the Herschel Space Telescope as part of KINGFISH (Key Insights on Nearby Galaxies: a Far Infrared Survey with Herschel; P.I.: R.C. Kennicutt), one of the Herschel Open Time Key Projects.

255.09

Angular Cross-correlation of Spitzer IRAC and Herschel Spire Sources

Ketron Mitchell-Wynne¹, A. Cooray¹, L. Wang², HerMES Consortium

¹UC Irvine, ²University of Sussex, United Kingdom.

Exhibit Hall

The Spitzer Deep Wide-Field Survey (SDWFS) and the Herschel Multi-tiered Extragalactic Survey (HerMES) each provide deep and wide coverage, centered on the Bootes field, at infrared and submillimeter wavelengths. The SDWFS covers approximately 8.5 square degrees with sensitivities of galaxies out to z ~ 3. From the public SDWFS source catalog, we remove stars and contaminants by concentration, using selection methods based on IRAC and optical colors; optical photometry is provided by the NOAO Deep Wide-Field Survey. Photometric redshifts of detected IRAC sources are then determined using the 1.6 micron spectral feature (or 'bump'). We classify three different kinds of bumps, (bump 1- bump 3), with redshifts ranging approximately from 0-1.3, 1.3-2, and 2-3 respectively. The number of bump 1 sources in the SDWFS catalogs were found to be in excess of 25,000 at the 5 sigma detection limit of the 3.6 micron channel of the IRAC instrument. Bump 2 and bump 3 source identification yielded similar, but slightly fewer counts. We also extract a separate catalog of 2500 or so dust-obscured galaxies (DOGs) at z~2 using 24 micron and r-band fluxes. As part of HerMES observations with SPIRE, the Bootes field contain more than 15,000 clearly detected SPIRE sources at 250 microns, In this paper we report on the cross correlation function of these bump sources with the source catalogs from three bands of the SPIRE instrument onboard Herschel. The aim is to broadly reconstruct the redshift distribution of SPIRE sources using redshift distributions of bump and DOGs in the bootes field and the relative clustering strengths.

Spitzer IRAC Identification of Counterparts to Herschel-ATLAS Sources with the Likelihood Ratio Test Sam Kim¹, A. Cooray¹, A. A. Khostovan¹, Herschel-ATLAS Consortium

¹UC Irvine.

Exhibit Hall

The Herschel-ATLAS Science Demonstration Phase field covers 14 square degrees in the GAMA survey 9hour field. We have imaged 0.5 sq. degree of this area with Spitzer IRAC and have complemented with existing IRAC data in the Spitzer archive. The area overlaps with about 200 Herschel SPIRE sources. We apply a likelihood ratio (LR) and reliability (R) technique to match IRAC sources with SPIRE sources. We find 391 and 451 potential counterparts at 3.6 um and 4.5 um respectively for the area of 10" radius range around these sources. We found that there are about hundred sources which are reliable enough to be Spitzer counterparts (R > 0.8). About 10% of sources within our sample has no SDSS counterparts. There is a possible limitation of the LR method because LR technique assumes that there is only one true counterpart to a given 250 um source. Multiple counterparts might be related to interacting or lensing system.

255.11

Herschel SPIRE Legacy Survey (HSLS)

Asantha R. Cooray¹

¹UC Irvine.

Exhibit Hall

A large sub-mm survey with Herschel will enable many exciting science opportunities, especially in an era of wide-field optical and radio surveys and high resolution cosmic microwave background experiments. The Herschel-SPIRE Legacy Survey (HSLS), will lead to imaging data over 4000 sq. degrees at 250, 350, and 500 micron. Major Goals of HSLS are: (a) produce a catalog of 2.5 to 3 million galaxies down to 26, 27 and 33 mJy (50% completeness; 5 sigma confusion noise) at 250, 350 and 500 micron, respectively, in the southern hemisphere (3000 sq. degrees) and in an equatorial strip (1000 sq. degrees), areas which have extensive multi-wavelength coverage and are easily accessible from ALMA. Two thirds of the of the sources are expected to be at z > 1, one third at z > 2 and about a 1000 at z > 5. (b) Remove point source confusion in secondary anisotropy studies with Planck and ground-based CMB data. (c) Find at least 1200 strongly lensed bright sub-mm sources leading to a 2% test of general relativity. (d) Identify 200 proto-cluster regions at z of 2 and perform an unbiased study of the environmental dependence of star formation. (e) Perform an unbiased survey for star formation and dust at high Galactic latitude and make a census of debris disks and dust around AGB stars and white dwarfs.

In the unlikely event HSLS is not selected by ESA HOTAC, the poster will present recent results from the Herschel-ATLAS survey, the largest open-time key program aimed at covering 500 square degrees.

255.12

GOODS-Herschel: The Deepest Far-infrared View Of The Distant Universe

Mark Dickinson¹, D. Elbaz², GOODS-Herschel team

¹NOAO, ²CEA, France.

Exhibit Hall

GOODS-Herschel is an open time key program using the Herschel Space Observatory to obtain the deepest far-infrared view of the distant universe. We have surveyed the GOODS-North field with PACS and SPIRE to very faint fluxes at 100-500 microns, and have also completed an ultradeep PACS observation at 100 and 160 microns covering about 1/4th of GOODS-South to the faintest depths yet reached by Herschel. The data permit the measurement of bolometric luminosities and dust spectral

energy distributions for "normal" ultraluminous galaxies and AGN at the peak era of galaxy formation, and may detect dusty starbursts out to z=3-4 and perhaps beyond. We present the GOODS-Herschel data and show some early science results.

255.13

Spitzer Imaging of Herschel-ATLAS Gravitationally Lensed Submillimeter Sources

Ali Ahmad Khostovan¹, A. Cooray¹, S. Kim¹, R. Hopwood², M. Negrello², H-ATLAS Consortium ¹University of California, Irvine, ²The Open University, United Kingdom. Exhibit Hall

In this study, we present two submillimeter selected gravitiational lensed sources and their 3.6 and 4.5 μ m properties that were identified in the *Herschel* Astrophysical Tetrahertz Large Area Survey (H-ATLAS). Due to their flux densities being > 100 mJy at 500 μ m makes these submillimeter galaxies (SMGs) not observable when using traditional optical selection methods for lensing events. We determined several important constrains on the SMG spectral energy distributions (SEDs) of these two sources by fitting light profiles to each foreground gravitational lens in the *Spitzer* IRAC data and successfully disentangling the foreground lens and background source components. Our results from the SED fitting shows that these two SMGs are highly obscured by dust with $A_v \sim 4$ to 5, stellar masses of $\sim 3 \times 10^{11}$, and star formation rates of 100 and 150 M_☉ yr⁻¹. By combining H₂ molecular masses from previously reported CO(1-0) line intensities, we determined that the gas fraction relative to stellar masses is at the level of 5% to 8% for the two galaxies.

255.14

Probing The Z~2.5 Lensed Galaxy Smm J163554.2+661225 With Herschel Spire Observations

Keely D. Finkelstein¹, C. Papovich¹, S. L. Finkelstein¹, E. Egami², M. Rieke², J. R. Rigby³, G. Rudnick⁴, J. T. Smith⁵, C. N. A. Wilmer²

¹Texas A&M University, ²Steward Observatory, University of Arizona, ³Goddard Space Flight Center, ⁴University of Kansas, ⁵Ritter Observatory, University of Toledo.

Exhibit Hall

We present Herschel observations of SMM J1633554.2+661225, which is a galaxy at z = 2.515 that is gravitationally lensed by the galaxy cluster Abell 2218, with a magnification of 22. Using the Herschel SPIRE 250, 350, & amp; 500 micron observations, which span the peak of dust emission at this redshift, we derive a more robust infrared luminosity and measure the dust temperature for the first time. These new Herschel results are compared to the Spitzer results of this galaxy, specifically the Herschel derived star formation rate (SFR) is compared with the previous Spitzer SFR, based on Paschen-alpha emission.

255.15

Protostars in Orion: New results from the Herschel Orion Protostar Survey Key Program

Babar Ali¹, W. Fischer², T. Megeath², J. Tobin³, C. Poteet², L. Hartmann³, D. Watson⁴, M. Puravankara⁴, L. Allen⁵, A. Stutz⁶, O. Krause⁶, T. Henning⁶, T. Stanke⁷, E. Bergin³, N. Calvet³, S. Maret⁸, E. Furlan⁹, D. Neufeld¹⁰, M. Osorio¹¹, T. Wilson¹²

¹NHSC/IPAC/Caltech, ²University of Toledo, ³University of Michigan, ⁴University of Rochester, ⁵NOAO, ⁶Max-Planck Institute Fur Astronomie, Germany, ⁷ESO, Germany, ⁸Laboratoire d'Astrophysique de Grenoble, France, ⁹JPL/Caltech, ¹⁰Johns Hopkins University, ¹¹Instituto de Astrofisica de Andalucia, Spain, ¹²Naval Research Lab.

Exhibit Hall

We present new far-IR photometry results on 131 proto-stars from the Herschel Orion Protostar Survey (HOPS). HOPS is a 200-hour Herschel key program that will systematically survey 286 protostars encompassing a wide range of source luminosities, evolutionary phases, and environments in a single molecular cloud in the 60-210 micron window where we will sample the peak of the thermal emission

from the protostellar envelope. We will focus on PACS imaging at 70 and 160 um taken as part of the imaging component of the HOPS program. From these data we extract 70 and 160 um photometry which are then combined with existing ground-based and HST near-IR imaging, IRAC and MIPS 3-24 um photometry and IRS 5-35 um spectra to create 1.6-160 um SEDs. These SEDS are integrated to find the bolometric luminosities and compared to the results of radiative transfer models (Whitney et al. 2003, ApJ, 591, 1049) to constrain the envelope morphologies, envelope densities, and infall rates. Our initial results (Fischer et al. 2010, A&A, 518, L122) on only protostars 4 stars showed a range of evolutionary states for the protostars. In this contribution, we extend our sample to 131 protostars -- the first large survey of its kind in the far-IR. We will examine the distribution of luminosities and SED properties as a function of environment. We will also present preliminary fits to radiative transfer models of the protostars.

256

Planetary Nebulae and Supernova Remnants Poster Session *Exhibit Hall*

256.01

Imaging Final Flash Objects in the Near-IR Kenneth H. Hinkle¹, R. R. Joyce¹ ¹NOAO.

Exhibit Hall

A post-AGB helium shell burning episode is a brief yet common evolutionary process for low mass stars. The final helium shell flash occurs after the star has ejected a planetary nebula and has started on the white dwarf track. Due to the brief $\sim 10^4$ yr duration of this event very few final flash objects are known. We present K_s band and He I 10830 A AO images for four of these objects. The images were obtained with both NIRI/Altair at Gemini and WHIRC/WTTM at WIYN and have spatial resolutions as high as 0.11 arcseconds. These results provide a good comparative test of the capabilities offered by these two instruments. The images show the cloud of ejecta produced by the final flash. We discuss the age of the ejecta in the context of a unifying model.

256.02

The Evolving Structure of CRL2688: 14 Years of HST Images

Bruce Balick¹, T. Gomez¹, J. Alcolea², D. Vinkovic³, R. Corradi⁴, A. Frank⁵ ¹Univ. of Washington, ²Observatorio Astronómico Nacional (IGN), Spain, ³Physics Department, University of Split, Croatia, ⁴Instituto de Astrofísica de Canarias, Spain, ⁵Univ. of Rochester. Exhibit Hall

The history of mass loss and chemical enrichment is inscribed on the nebulae surrounding post-AGB stars. Of these objects the most prominent record is the circumnuclear region of the Egg Nebula. We present changes in structure and surface brightness of CRL2688 derived from several pairs of Hubble Space Telescope images taken between 1995.5 and 2009.6 in the F606W filter. We find that over the course of 6.7 y the N and S lobes brightened by 15% and 30%, respectively, and both lobes grew nearly uniformly from the illuminating star with a kinematic age of 266±25y. The ensemble of surrounding arcs brightened by 10-25%. We are analyzing the data with the intent of determining whether the growth pattern of the ensemble of quasi-circular arcs is constant proper motion per arc [(dr/dt) = constant] or uniform [(dr/dt) \propto r]. In addition we present new four-color images of CRL2688 and use them to model the geometric distribution and scattering properties of the dust.

256.03 Jets in Pre-Planetary Nebulae Patrick J. Huggins¹, C. L. Cheung¹

¹New York University. Exhibit Hall

High velocity jets are common features of the transition from Asymptotic Giant Branch stars to planetary nebulae (PNe), but their origins are not well understood. A promising scenario is that jets are launched by the accretion disks of companion stars, which are fed by mass loss from the primary during the pre-PN phase. We examine this scenario using prescriptions for the mass fraction captured by the companion and the efficiency of jet launching from disks. We explore the dependence of jet properties on the mass loss and binary parameters, and compare the results with measurements of jet momentum and toroidal mass in a sample of well studied pre-PNe. Our findings are used to evaluate and constrain the companion-disk scenario. This work is supported in part by NSF grant AST 08-06910.

256.04

Unveiling the True Metallicity and Stellar Populations of Planetary Nebula Progenitor Stars Harriet L. Dinerstein¹, T. R. Geballe², N. C. Sterling³

¹Univ. of Texas, Austin, ²Gemini Obs., ³Michigan State Univ..

Exhibit Hall

We have measured the recently identified 3.625 micron [Zn IV] fine-structure line (Dinerstein & Geballe 2001, ApJ, 562, 515) in a dozen Galactic planetary nebulae (Dinerstein et al. 2007, BAAS, 211, 100.14). Because Zn is the least refractory of the Fe peak elements, the gas phase [Zn/H] abundance can be used as a proxy for the elemental [Fe/H] in the progenitor star, in contrast to Fe itself, which is heavily depleted into dust. We find that the observed Milky Way nebulae fall into two categories: objects which have roughly solar values of [Zn/H] and [O/Zn]; and nebulae with low Zn (clustering around [Zn/H] = -0.6) and elevated [O/H]. Most of the latter group have high radial velocities, $|v_{rad}| > 60$ km/s. Our interpretation is that the objects with solar abundances and low velocities originate from thin disk stars, while the nebulae with low Zn are descendants of thick disk stars. A further implication is that the common assumption that O and other alpha species are reliable indicators of metallicity in planetary nebulae is not necessarily valid, and can lead to erroneous conclusions about the parent stellar population. This effect is particularly acute for O since [O/Fe] can be large, especially in metal-poor populations. In a planetary nebula formed by a star with this abundance pattern, a high value of [(O, alpha)/Fe] can offset a low [Fe/H], producing near-solar abundances for O and other alpha species. This can make it appear that the star belongs to a more metal-rich (in [Fe/H]) population than is actually the case. Obtaining Zn abundances for larger samples of planetary nebulae will be crucial to disentangling these abundance ratios and breaking the potential degeneracy of the O and alpha abundances. (This research was supported by NSF grant 0708245.)

256.05

New Atomic Data for Neutron-Capture Elements and Their Application to Abundance Determinations in Ionized Nebulae

Nicholas C. Sterling¹, M. C. Witthoeft², D. A. Esteves³, R. C. Bilodeau⁴, E. C. Red⁵, A. L. D. Kilcoyne⁵, R. A. Phaneuf³, G. Alna'Washi³, A. Aguilar⁵

¹Michigan State University, ²NASA Goddard Space Flight Center, ³University of Nevada, ⁴Western Michigan University, ⁵Advanced Light Source (LBNL).

Exhibit Hall

The detection of neutron(n)-capture elements (atomic number Z>30) in the spectra of nearly 100 planetary nebulae (PNe; Sterling & Dinerstein 2008, ApJS, 174, 157) demonstrates that nebular

spectroscopy is a potentially powerful new tool to investigate n-capture nucleosynthesis and the chemical evolution of trans-iron elements in the Universe. Nebular spectroscopy provides access to several n-capture elements that are not detectable in cool giant stars, and enables investigations of classes of stars and stages of evolution in which stellar photospheres are obscured by heavy mass loss. However, the poorly known atomic data for processes that govern the the ionization balance of n-capture elements present a major challenge to investigations of these species in ionized nebulae. These data are needed to accurately estimate the abundances of unobserved n-capture element ions, and hence to determine the total elemental abundances of these species.

To address this issue, we have computed photoionization cross sections and radiative and dielectronic recombination rate coefficients for low-charge ions of the three most widely observed n-capture elements in PNe (Se, Kr, and Xe). These results are benchmarked to experimental absolute photoionization cross sections measured at the Advanced Light Source synchrotron radiation facility. We also computed charge transfer rate coefficients for these species with a multichannel Landau-Zener code. These new atomic data will be incorporated into photoionization codes to derive reliable ionization corrections for Se, Kr, and Xe. We will apply these results to determine the abundances of n-capture elements in PNe to unprecedented accuracy, enabling robust investigations of s-process nucleosynthesis in PN progenitor stars.

NCS acknowledges support from an NSF Astronomy and Astrophysics Postdoctoral Fellowship under award AST-901432.

256.06

What Causes the "Sulfur Abundance Anomaly" in Planetary Nebulae?

Jerica M. Green¹, K. Braxton¹, B. Balick¹, J. Lutz¹

¹University of Washington.

Exhibit Hall

It has been known for several years that planetary nebulae (PNe) follow a different relationship from other objects which have sulfur and oxygen emission lines in their spectra, e.g., H II regions, and Blue Compact Galaxies (BCGs) when log(S/H) is plotted versus log(O/H). The HII regions and BCGs show a rather tight linear relationship between log(S/H) and log(O/H) over several orders of magnitude in these abundances. However, PNe concentrate towards higher values of both log(S/H) and log(O/H) (except for a few halo PNe which have lower values) and generally don't follow the relationship defined by the HII regions and BCGs. We are investigating the cause of this apparent "sulfur anomaly" by using a sample of about 160 PNe which have abundances determined in a uniform fashion. We consider the derived abundances in combination with other nebular and stellar properties to investigate various possibilities that have been proposed (ionization correction factors don't account correctly for sulfur emission lines in IR/UV, sulfur not observed due to presence in grains/molecules, PNe oxygen abundances more enhanced than previously predicted).

256.07

The Galactic Disk Oxygen Gradient and the Limit of Confusion

Richard B. C. Henry¹, K. B. Kwitter², A. E. Jaskot³, B. Balick⁴, M. A. Morrison¹, J. B. Milingo⁵ ¹Univ. of Oklahoma, ²Williams College, ³University of Michigan, ⁴University of Washington, ⁵Gettysburg College.

Exhibit Hall

We have obtained spectrophotometric observations of 41 anticenter planetary nebulae (PNe) located in the disk of the Milky Way. Oxygen abundance results of these objects plus those in our pre-existing database yield a sample of 124 PNe with which to study the oxygen abundance gradient in the disk of the Galaxy between 0.9 and 21 kpc in galactocentric distance. Accounting for both abundance and

distance uncertainties, we find an oxygen gradient of -0.058 ± 0.006 dex/kpc. We see some evidence that the gradient may steepen at large galactocentric distances but no compelling evidence that the gradient differs between Peimbert Types I and II nor that the oxygen abundance is related to the vertical distance from the Galactic plane. A second analysis using PN distances from Stanghellini et al. (ApJ, 689, 194, 2008) implies a flatter gradient, and we suggest that we have reached a confusion limit which can only be resolved with greatly improved distance measurements and an understanding of the natural scatter in oxygen abundances. RBCH, KK, and BB gratefully acknowledge support from NSF Grants AST-0806577, AST-0806490, and AST-0880201, respectively.

256.08

Abundances in a Sample of Halo/Thick Disk Planetary Nebulae in M31

Karen B. Kwitter¹, E. M. Lehman¹, B. Balick², R. B. C. Henry³

¹Williams College, ²University of Washington, ³University of Oklahoma.

Exhibit Hall

We present preliminary abundances for 16 planetary nebulae in M31 identified by Merrett et al. (MNRAS, 369, 120, 2006). Our objects are the brightest 16 in a λ 5007 flux-ranked subsample (m₅₀₀₇ between 20.45 and 20.88) whose distances from the major axis of M31, measured parallel to the minor axis, are between 15 and 50 arcminutes. This group presumably includes non-thin-disk objects, i.e., members of the thick disk and halo of M31, but may also sample possible tidal streams. Spectroscopic data were obtained with the DIS instrument on the 3.5-m ARC telescope at Apache Point Observatory (3700-9600 Å) and with GMOS on the Gemini North 8.1-m telescope (3700-6400 Å). Abundances were derived using our ELSA package (Johnson et al., IAU Symp. #234, 439, 2006). The resulting preliminary average abundances based on observations to date are as follows: He/H=0.107(±0.010),

O/H=4.29(±1.24)x10⁻⁴, N/O=0.703(±0.618), and Ne/O=0.212(±0.019). There remain six PNe for which we have only Gemini spectra; in the fall of 2010 we plan to complete our observations and obtain companion red spectra at APO, allowing an improved analysis. For now, we note that the average He/H ratio is similar to the average of Milky Way halo PNe (Henry, Kwitter & Balick, A.J., 127, 2284, 2004), and below that for a similar-sized sample of mostly bulge PNe in M31 reported by Jacoby & Ciardullo (Ap.J., 515, 169, 1999). Our O/H ratio is well above the Milky Way halo PN value, and slightly above that of the Jacoby & Ciardullo sample.

KBK, RBCH and BB are grateful to their respective institutions and to the NSF for support under grants #AST-0806490, AST-0806577, and AST-0880201, respectively. KBK and EML thank NOAO for their generous travel support.

256.09

Spectra of 12 New Planetary Nebulae in the Milky Way Galaxy

Jean McKeever¹, T. Gomez¹, B. Balick¹, J. Lutz¹, K. Kwitter², S. Snedden³

¹University of Washington, ²Williams College, ³Astrophysical Research Consortium.

Exhibit Hall

There are many planetary nebulae known in our own galaxy, but the vast majority are located close to the plane. However studies of M31 show thousands of PN in its thick disk and halo, so we surmise that there are more halo PN to be discovered for the MWG. Halo PN are important for studying the chemical evolution of the MWG, since they reflect the composition of the galaxy when the first generation of stars formed. We have been searching for PN within the galactic halo, and have found three new PN that may be classified as "halo" PN. We have also discovered nine other new PN within the thick disk and plane of the galaxy. Candidates for our spectral observations were chosen through a multi-step process. First, colors within SDSS and 2MASS were compared to find initial targets, which were then followed up with imaging in g' and [OIII] filters to pick out [OIII] bright candidates. Apache Point

Observatory DIS spectroscopy of our candidates has resulted in indentification of tweleve likely new PN, based on the observed emission lines, and ratios of these lines. We present spectra and images of some for these targets.

256.10

The Physical Characteristics of Close Binary Central Stars of Planetary Nebulae Todd C. Hillwig¹

¹Valparaiso University.

Exhibit Hall

The number of detected close binary stars in planetary nebulae has increased dramatically in the past several years and is now reaching the level at which statistically significant trends may be made discussed. Several of the important parameters we would like to know are binary fraction of central stars, system classifications, binary parameters (such as inclination), and correlations between the binary and its surrounding planetary nebula. I

will describe the sample of known close binary central stars

in relation to other close binaries with a white dwarf, including cataclysmic variables, supernova la progenitors, and double degenerate systems. I will also review the system parameters for well studied systems and relate these, where possible, to their associated nebulae.

256.11

Modeling the Binary Central Star of PN Hf 2-2

Samuel Clay Schaub¹, T. C. Hillwig¹

¹Valparaiso University.

Exhibit Hall

In our quest to understand the shaping mechanisms of planetary nebulae, we have modeled the known binary central star Hf 2-2. The models have been matched to photometric variation data in B, V and R filters. Our goal was to constrain as much as possible the fundamental properties of the binary system: the masses, temperatures, and radii of each star as well as the inclination angle of the system. These constrained system properties, especially the inclination angle, can then be compared with the predictions of the theory that binary stars are responsible for the complex shapes we see in planetary nebulae. The inclination angle for Hf 2-2 has been constrained to the range of 25°-55°. From visual inspection of the nebula, the inclination angle range of Hf 2-2 includes alignment with the nebula, though thorough modeling of the nebular structure is necessary to draw an unambiguous conclusion.

256.12

Expansion of the Youngest Galactic Supernova Remnant G1.9+0.3

Ashley Carlton¹, K. J. Borkowski², S. P. Reynolds², R. Willett³, K. Krishnamurthy³, D. A. Green⁴, R. Petre⁵ ¹Wake Forest University, ²North Carolina State University, ³Duke University, ⁴Cambridge University, United Kingdom, ⁵NASA/GSFC.

Exhibit Hall

Tracking the increase in size of supernova remnant G1.9+0.3, the remains of the most recent stellar explosion in our Galaxy, yields the approximate time since the original supernova. We calculate an average global expansion rate by comparing images obtained with NASA's Chandra X-ray Observatory in February 2007 and July 2009. We assume the remnant has expanded uniformly by some factor, and allow for a possible change in X-ray brightness by another factor, with a possible shift in expansion center. The model depends on four parameters: scale, brightness, and position shifts. We estimate parameter values and confidence intervals using both C-statistics and Markov chain Monte Carlo simulations; the results are essentially identical. We find expansion of 0.62±0.050% per year, making the time from explosion 160±15 years, in the absence of deceleration. While these data cannot constrain

deceleration, it has most likely occurred, with the remnant expanding faster in the past, making these results an upper limit on the age of the remnant. The mean expansion is consistent with the rates obtained in a previous study, but with smaller errors. We find that the remnant has increased in brightness, as well, by a rate of about 3% per year. Preliminary results also suggest more rapid expansion (in comparison to the average) in the East and West lobes, and slower expansion in the radio bright region to the North.

256.13

Systematic Spatial Variations of the Spectrum of Synchrotron X-rays from the Youngest Galactic Supernova Remnant G1.9+0.3

Stephen P. Reynolds¹, K. Borkowski¹, U. Hwang², D. A. Green³, R. Willett⁴, K. Krishnamurthy⁴ ¹North Carolina State Univ., ²NASA/GSFC, ³Cavendish Laboratory, Cambridge University, United Kingdom, ⁴Duke Univ..

Exhibit Hall

The youngest Galactic supernova remnant G1.9+0.3 shows an X-ray spectrum dominated by synchrotron emission, with a simple bilaterally symmetric morphology resembling SN 1006. We observed G1.9+0.3 for 236 ks with Chandra in July 2009. We describe the nonthermal emission spectrum with a simple model of a power-law with exponential cutoff at energy Emax (XSPEC model srcut) and demonstrate systematic variations of the rolloff frequency (peak frequency emitted by electrons with Emax) with position. Extensions beyond the bright shell to E and W ("ears") have the highest values of rolloff (26 keV in the E and 12 in the W). Moving inward, spectra become softer, with a value of rolloff in the remnant interior of 0.6 keV, indicating a combination of synchrotron and adiabatic losses. The fainter quadrants of the X-ray shell have lower rolloff values. This pattern is similar to what is observed in SN 1006 and may indicate obliquity-dependence of the electron acceleration rate. We discuss the constraints on models of particle acceleration provided by these results, and by the observed brightening of the integrated X-ray flux (reported elsewhere) of about 3% per year.

256.14

The Young, Galactic Supernova Remnant G350.1-0.3 and Its Neutron Star: A Study with Chandra

Igor Lovchinsky¹, P. Slane¹, B. M. Gaensler², J. P. Hughes³, C. Ng⁴, J. S. Lazendic⁵, J. Gelfand⁶, C. Brogan⁷ ¹Harvard-Smithsonian Center for Astrophysics, ²Sydney Institute for Astronomy, School of Physics, The University of Sydney, Australia, ³Rutgers University, The State University of New Jersey, ⁴Department of Physics, McGill University, Canada, ⁵School of Physics, Monash University Clayton, Australia, ⁶New York University Abu Dhabi, United Arab Emirates, ⁷National Radio Astronomy Observatory. Exhibit Hall

We present a new *Chandra* observation of supernova remnant (SNR) G350.1-0.3. The high resolution Xray data reveal previously unresolved filamentary structures and allow us to perform detailed spectroscopy in the diffuse regions of this SNR. Spectral analysis demonstrates that the region of brightest emission is dominated by hot, metal-rich ejecta while the ambient material along the perimeter of the ejecta region and throughout the remnant's western half is mostly low-temperature, shocked interstellar/circumstellar medium (ISM/CSM) with solar-type composition. The data reveal that the emission extends far to the west of the ejecta region and imply a lower limit of 6.6 pc on the diameter of the source (at a distance of 4.5 kpc). We show that G350.1-0.3 is likely in the free expansion (ejecta-dominated) stage and calculate an age of 600 - 1200 years. The derived relationship between the shock velocity and the electron/proton temperature ratio is found to be entirely consistent with that of other SNRs. We perform spectral fits on the X-ray source XMMU J172054.5-372652, a candidate central compact object (CCO), and find that its spectral properties fall within the typical range of other CCOs. We also present archival 24 µm data of G350.1-0.3 taken with the *Spitzer Space Telescope* during the MIPSGAL galactic survey and find that the infrared and X-ray morphologies are well-correlated. These results help to explain this remnant's peculiar asymmetries and shed new light on its dynamics and evolution.

256.15

The Proper Motion of the Neutron Star in Cassiopeia A

Joseph Satterfield¹, T. DeLaney¹, S. Chatterjee²

¹West Virginia Wesleyan College, ²Cornell University.

Exhibit Hall

We used data from the High Resolution Camera on the Chandra X-ray Observatory to measure the proper motion of the neutron star in Cassiopeia A over a baseline of 10 years. Our measurement indicates that the neutron star is moving at 450 +/- 200 km/s in the south-southeast direction. This motion is completely consistent with the inferred proper motion based on the offset of the neutron star from the center of expansion of the optical ejecta. We will discuss how this motion relates to the other features in Cas A, such as the jets, the Fe-rich ejecta to the north and southeast, and gaps in the outer optical knot distribution.

256.16

Spectral Evolution in Cassiopeia A Observed with Chandra's High Energy Transmission Grating

Tracey DeLaney¹, D. Dewey², E. Figueroa-Feliciano², S. Trowbridge², J. Rutherford²

¹West Virginia Wesleyan College, ²Massachusetts Institute of Technology.

Exhibit Hall

We obtained a new observation of Cassiopeia A with the High Energy Transmission Grating on board the Chandra X-ray Observatory in April 2010 in order to compare with the first observation taken in May 2001 and search for evolution in the spectral lines. Our preliminary analysis of the 17 regions measured in 2001 shows mostly small changes in the Si XIII f/r ratio and Si H/He ratio, however, one region showed a significant change in the Si H/He ratio The H/He ratios have typically increased - indicating increasing ionization - or stayed the same. The velocities of the regions have all decreased or remained the same and the speed changes may be correlated with the Si XIII f/r ratio. We will perform an analysis of the ACIS data on these regions to obtain values of temperature and ionization age and we will compare the evolution we actually observe with the changes expected from evolutionary models.

256.17

No Place to Hide? Separating Thermal and Non-Thermal X-ray Emission Along the Line of Sight in the Cas A SNR

Michael D. Stage¹, G. E. Allen²

¹Mount Holyoke College, ²MIT Kavli Institute.

Exhibit Hall

Observations of few-keV synchrotron radiation emitted by accelerated electrons in supernova-remnant shocks using telescopes such as Chandra and XMM has provided strong evidence that acceleration of (Galactic) cosmic rays is occurring through the diffusive shock acceleration mechanism. These same remnants often show a power-law-like higher energy X-ray spectrum when observed with telescopes such as Suzaku or the Rossi X-ray Timing Explorer. In the past we have used a spatially-resolved spectroscopic analysis of Chandra extrapolate the integrated synchrotron spectrum for such remnants, and preliminary results suggest there is not enough total synchrotron emission to explain the high energy spectrum--we conclude emission is likely also contributed from non-thermal electrons through bremsstrahlung. However, the calculations are difficult because of projection effects; thermal emission of remnant ejecta is bright in the spatially-resolved band and some lines-of-sight may contain regions emitting through multiple mechanisms. Here we consider what fraction of synchrotron radiation might

be "missed" in our integrated spectrum by fitting simulated spectra containing both thermal and synchrotron emission with appropriate values for Cas A. This work is supported by the Chandra General Observer Program Grant AR9-0008X.

256.18

A Chandra ACIS Observation of the Pulsar-Wind Remnant RCW 103

Estela Jordan¹, E. M. Schlegel¹

¹Univ of Texas at San Antonio.

Exhibit Hall

We describe spatially-resolved, CCD-resolution spectroscopy of the supernova remnant (SNR) RCW 103 as observed by the Chandra X-ray Observatory during a 19.1 ksec exposure. The outstanding spatial resolution of the Chandra ACIS images resolve diffuse filaments across the remnant, as well as what appear to be explosion fragments, or "bullets," extending beyond the x-ray bright region in the southwestern part of the SNR. Observed features are soft (E < 3 keV) and we detect evidence of line emissions at several energies. The x-ray bright regions in the southwestern and northeastern part of RCW 103 are consistent with enhancements of optical, infrared, and radio emissions.

256.19

Time Evolution of the Reverse Shock in SN 1006

P. Frank Winkler¹, K. S. Long², R. A. Fesen³, A. J. S. Hamilton⁴

¹*Middlebury College,* ²*Space Telescope Science Institute,* ³*Dartmouth College,* ⁴*Univ. of Colorado. Exhibit Hall*

The Schweizer-Middleditch star, located behind the SN 1006 remnant and near its center in projection, provides the opportunity to study cold, expanding ejecta within the SN 1006 shell through UV absorption. Especially notable is an extremely sharp red edge to the Si II 1260 Ang. feature. Using spectra obtained with COS in 2010, and comparing with ones obtained with STIS in 1999, we have measured changes in this and other features over the intervening 10+ year baseline. We find that the Si II edge has shifted to the blue by about 0.1 Ang, which means that the reverse shock has slowed by about 2.3 km/s per year. This is the first observational confirmation of this predicted dynamic effect for a reverse shock: that the shock will apparently decelerate as it works its way inward through expanding supernova ejecta, encountering ever slower material as it proceeds. This research is supported by NASA Grant HST-GO-11659-01-A.

256.20

Simulations of Supernova Reverse Shock Dust Destruction in Metal-Enriched Clouds Devin W. Silvia¹, B. D. Smith², J. M. Shull¹

¹University of Colorado - Boulder, ²Michigan State University. Exhibit Hall

In following previous work, we present hydrodynamic simulations used to study the effects of dust destruction by sputtering in the reverse shocks of supernova remnants. As before (Silvia et al. 2010), we use an idealized setup of a planar shock impacting a dense, spherical clump implanted with a population of Lagrangian particles that act as tracers of dust. These tracers represent a distribution of dust grains that vary in both species and size. Specifically, we investigate those cases in which the cloud initially has super-solar metal abundances (Z ~ 1000 Z_{\odot}), as we expect the ejecta knots from supernova explosions to be extremely metal-enriched. A high abundance of metals has significant influence on both the cooling properties of the cloud and the thermal sputtering rates of the embedded dust grains. We also include a brief discussion about the difficulty of using the piecewise parabolic method for solving the hydrodynamic equations with high cooling rates produced by high metallicities. Through these simulations, we seek to quantify the fragmentation of ejecta clumps for comparison to observations of

nearby supernova remnants and calculate the dust survival rate for these heavily metal-enriched cases. Estimates for dust survival in supernova shocks is critical in determining the source of dust at high redshift.

256.21

Spitzer Mapping of RCW 86: Examining Small Spatial Scales in the Post Shock Environment Brian J. Williams¹, K. J. Borkowski¹, S. P. Reynolds¹, K. S. Long², P. F. Winkler³, W. P. Blair⁴, P. Ghavamian², J. C. Raymond⁵, J. Rho⁶

¹North Carolina State Univ., ²Space Telescope Science Institute, ³Middlebury College, ⁴Johns Hopkins University, ⁵Harvard-Smithsonian Center for Astrophysics, ⁶SOFIA/USRA. Exhibit Hall

We present a mid-IR mapping observation of the supernova remnant RCW 86, the proposed remnant of SN 185 A.D. and a source of TeV gamma-rays, obtained with the MIPS and IRAC instruments on Spitzer. The entire shell is detected at 24 μ m, and the remnant's large size combined with Spitzer's resolution allow study on small spatial scales (~ 0.1 pc). Emission from both radiative and non-radiative regions is observed, attributable primarily to warm dust in the ISM heated by the shock. Short-wavelength images show emission in the bright southwest corner, where radiative shocks dominate. Strong emission from the southwest is also observed at 70 μ m, as is a thin filament in the northwest portion of the remnant. This filament has a 70/24 flux ratio of 3.3, and is spatially coincident with a filament seen in archival X-ray images from XMM-Newton. A plane-shock model with variable abundances, a temperature of 0.33 keV and ionization timescale of 1.67×10^{11} cm⁻³ s and an additional non-thermal component provide a good fit to the X-ray data. We use these parameters and assume a shock speed of 600 km s⁻¹ to fit a dust model to IR data, finding a post-shock gas density of $n_p = 8.0$ cm⁻³ and a dust mass of ~ 7.5×10^{-4} M_{\odot}. From the X-ray emission measure of the thermal component, we find a swept gas mass of 0.75 M_{\odot} in this region, giving a dust-to-gas mass ratio of 2.5 × 10⁻³, a factor of several lower than what is expected in the Galactic ISM, even accounting for sputtering of dust grains by energetic ions. Accounting for this discrepancy would require a significant mass in dust to be too cold to emit efficiently at 70 μm. We find some evidence for cosmic ray modification of the shock front.

256.22

Spitzer Imaging and Spectroscopy of the XA Region in the Cygnus Loop Supernova Remnant Ravi Sankrit¹, J. C. Raymond², T. J. Gaetz², W. P. Blair³, B. J. Williams⁴, K. J. Borkowski⁴, S. P. Reynolds⁴, K. S. Long⁵, P. Ghavamian⁵

¹SOFIA/USRA, ²Smithsonian Astrophysical Observatory, ³Johns Hopkins University, ⁴North Carolina State University, ⁵STScl.

Exhibit Hall

Spitzer MIPS 24mu-m and 70mu-m images and IRS high-resolution spectra of the XA region in the Cygnus Loop supernova remnant are presented. Many collisionally excited infrared lines are seen in the spectrum of an optically bright knot in the post-shock region. In contrast, a spectrum obtained at the shock front contains only a few high ionization lines. The infrared line fluxes, along with previously obtained far-ultraviolet line fluxes, are used to obtain the Neon to Oxygen abundance ratio in the shocked gas. The fluxes in the two MIPS images are corrected for contributions from lines and their ratio is used to characterize the dust emission and dust destruction in the shocked region.

Interstellar Lithium and Rubidium in the Diffuse Gas Near IC 443

Adam M. Ritchey¹, C. J. Taylor¹, S. R. Federman¹, D. L. Lambert²

¹University of Toledo, ²University of Texas at Austin.

Exhibit Hall

We present an analysis of interstellar lithium and rubidium from observations made with the Hobby-Eberly Telescope at McDonald Observatory of the Li I λ 6707 and Rb I λ 7800 absorption lines along four lines of sight through the supernova remnant IC 443. The observations probe interstellar material polluted by the ejecta of a core-collapse (Type II) supernova and can thus be used to constrain the contribution from massive stars to the synthesis of lithium and rubidium. Production of ⁷Li is expected to occur through neutrino spallation in the helium and carbon shells of the progenitor star during the terminal supernova explosion, while both ⁶Li and ⁷Li are synthesized via spallation and fusion reactions involving cosmic rays accelerated by the remnant. Gamma-ray emission from IC 443 provides strong evidence for the interaction of accelerated cosmic rays with the ambient atomic and molecular gas. Rubidium is also produced by massive stars through the weak *s*-process in the He- and C-burning shells and the *r*-process during core collapse. We examine interstellar ⁷Li/⁶Li isotope ratios as well as Li/K and Rb/K ratios along each line of sight, and discuss the implications of our results in the context of nucleosynthesis associated with Type II supernovae.

256.24

The Cosmic Ray Yield Of Supernova Remnants IC 443 And Puppis A

John W. Hewitt¹

¹NASA/GSFC.

Exhibit Hall

Supernovae have long been thought responsible for accelerating Galactic cosmic rays. Recent observations with the Fermi Gamma-ray Space Telescope clearly identify GeV energy emission towards several supernova remnants. Combining data from radio to gamma-rays, we assemble the broadband spectral energy distribution of IC 443 and Puppis A, supernova remnants which are interacting with molecular clouds and have spatially extended gamma-ray emission. We account for strong infrared emission from shock heated dust which contributes significantly to inverse Compton gamma-ray emission. Spectral breaks are detected at both radio and gamma-ray wavelengths, placing constraints on the underlying relativistic particle distribution responsible for nonthermal emission. We discuss the implications of our results for the yield of cosmic rays accelerated during the evolution of supernova remnants.

256.25

Studying The Hi Emission Of Supernova Remnants In The I-GALFA Survey

Chelsea Vincent¹, J. Kang²

¹University of Pittsburgh, ²Arecibo Observatory.

Exhibit Hall

A search for expanding, HI shells around galactic supernova remnants (SNR) was conducted using the Inner Galactic Plane Arecibo L-band Feed Array (I-GALFA) HI survey. This survey, which mapped out the distribution of HI emission within the galactic plane, spanned an area that included a total of thirty eight SNR positions. HI intensity was viewed over a velocity range of -150 km/s to +150 km/s, of which five SNRs were found to have an associated expanding HI shell, ten to have central HI emission, and six to have some HI absorption. The SNR G65.3+5.7 was selected to study more in depth because it appears to have HI emission that correlated with the optical and radio continuum emission. This supernova remnant has a very bright optical shell dominated by OIII emission with x-ray radiation at its center. The

HI emitting shell was visible within the velocity range of -12 km/s to +10 km/s, which overlaps the systematic velocity of 8 ± 10 km/s derived in previous research, providing further evidence of the shell's association with the SNR. It was found to have a size of approximately 260' across, yielding a physical radius of 38pc at a distance of 1kpc. The observed HI shell mass was derived by extrapolating the temperature brightness of the shell and the background from the HI images and doing an integration to yield a value of ~2000 M_{solar} . This value was then used to calculate a hydrogen number density of 0.353 cm⁻³. Assuming an initial explosion energy of 10⁵¹ ergs and a metallicity of ~1, the expansion velocity of this shell was determined as 550 km/s and the age as approximately 21,000 years. These values for physical size, number density, expansion velocity, and age agree well with the values derived in previous optical, x-ray, and radio studies.

256.26

The Velocity Structure of HI Emission Toward Supernova Remnant HB9

Alice Griffeth¹, M. Castelaz², D. Moffett³

¹University of Chicago, ²Pisgah Astronomical Research Institute, ³Furman University. Exhibit Hall

Using Pisgah Astronomical Research Institute's (PARI) 26 meter West Radio Telescope, I investigated the velocity structure and overall presence of hydrogen in a region of the supernova remnant HB9 (Green, 2009). This was done by taking spectral data over a 142.5 by 127.5 arc minute grid surrounding the most intense region of hydrogen emission. The spectra were summed under the hydrogen peak to create an overall hydrogen map of the region. Spectra were also divided amongst different frequency channels to model the velocity structure of the hydrogen present in the region. My findings are compared with additional velocity and hydrogen composition maps (Leahy & Roger, 1991).

256.27

Supernova Remnant 1987A at High Resolution

Chi Yung Ng¹, T. M. Potter², L. Staveley-Smith², B. M. Gaensler³, S. S. Murray⁴, S. Tingay⁵, C. Phillips⁶, A. K. Tzioumis⁶, G. Zanardo²

¹McGill University, Canada, ²The University of Western Australia, Australia, ³The University of Sydney, Australia, ⁴Johns Hopkins University, ⁵Curtin University, Australia, ⁶ATNF, Australia. Exhibit Hall

We present high resolution radio and X-ray observations of supernova remnant 1987A. VLBI imaging at 1.4 and 1.7 GHz taken in 2007 and 2008 with the Australian Long Baseline Array provides the highest resolution radio images of the remnant to date, revealing two extended lobes with an overall morphology consistent with observations at lower resolutions. We find evidence of small-scale features in the radio remnant, which possibly consist of discrete clumps near the inner surface of the shell. These features have spatial extent smaller than 0.2" and contribute less than 13% of the total remnant flux. We also report new X-ray observation taken in 2010 August with the High Resolution Camera onboard the Chandra X-ray Observatory. Comparing to the 2008 April exposure with the same instrument, the remnant flux increased by 43% in the 0.08-10 kev range and the relative brightness of the X-ray lobes around the shell show significant variability. In particular, the western half of shell is now ~15% brighter than the eastern half. No central compact object is found in the radio and X-ray images. We compare the detection limits to previous studies and discuss the physical implications.

The Australia Long Baseline Array is part of the Australia Telescope which is funded by the Commonwealth of Australia for operation as a National Facility managed by CSIRO.

Evolution of the High Velocity X-Ray Emission in SN 1987A

Daniel Dewey¹, F. Haberl², V. V. Dwarkadas³, D. N. Burrows⁴, S. Park⁵ ¹*MIT Kavli Institute,* ²*MPE, Germany,* ³*U Chicago,* ⁴*Penn State,* ⁵*U Texas.*

Exhibit Hall

Chandra HETG observations of SN 1987A in late 1999 showed very broad lines with observed FWHM of order 7000 km/s (Michael et al. 2002). At this time (SN day ~ 4600) the blastwave was already interacting with the H_{II} region around the progenitor and optical spots had recently appeared. High-resolution spectra taken from May 2003 (~ day 5900) to the present by XMM-Newton and Chandra have been well fit by models with FWHM less than 2000 km/s (Zhekov et al. 2005; Dewey et al. 2008; Sturm et al 2010). The emission is increasingly dominated by these narrower components as the blastwave encounters more of the dense equatorial ring. However emission from the H_{II} region out of the ring plane is still expected at late times and would contribute a high-velocity component to the spectra. We analyze 6 epochs of SN 1987A grating data and include an additional very broad component in the spectral model. We find that deep HETG 2007 data are better fit when one quarter of the flux comes from a component with FWHM ~ 8500 km/s, and that RGS 2003 data show an improved fit with a very-broad fraction that is between the 1999 and 2007 values. Later data continue a progression to lower, but still significant, very-broad fractions. The measurements are discussed in terms of the density and extent of the out-of-plane H_{II} region, hydrodynamical simulations, and 3D models of SN 1987A's emission.

Support for this work was provided by NASA/USA through contract NAS8-03060 to the Smithsonian Astrophysical Observatory (SAO) and further SAO sub-contracts TM9-0004X to VVD (U Chicago) and SV3-73016 to MIT for support of the CXC.

256.29

Status and Statistics of the Multi-wavelength Magellanic Cloud SNR Database

Rosa Nina Murphy Williams¹, J. R. Dickel², Y. Chu³, S. Points⁴, F. Winkler⁵, M. D. Johnson¹, K. Lodder¹, E. Randall¹

¹Columbus State University, ²University of New Mexico, ³University of Illinois, ⁴Cerro-Tololo Inter-American Observatory, Chile, ⁵Middlebury College.

Exhibit Hall

Supernovae (SNe), through their diffuse supernova remnants (SNRs), are primarily responsible for the injection of energy and heavy elements into the interstellar medium (ISM). SNe provide most of the hot gas component of the ISM, singly and through collective inputs to superbubbles (SBs). The energy and heavy elements influence future generations of star formation and profoundly affect galactic evolution. The Magellanic Clouds (MCs) contain SNRs at a wide variety of types, ages, evolutionary stages, and environments. The known, common distances and low obscuration of the MCs allows their SNRs to be studied as members of increasingly well-understood populations. Current instruments, such as the Chandra and XMM X-ray satellites and the Hubble and Spitzer Space Telescopes, have allowed high-resolution studies comparable to those for Galactic SNRs. Surveys of the MCs with the Australia Telescope Compact Array in radio, and the Magellanic Clouds Emission-Line Survey at CTIO, provide a wealth of data on these objects.

As part of a long-term multi-wavelength study of SNRs in the MCs, we have collaborated on a database of the Magellanic Cloud SNRs. This database serves to gather information, images and data on these SNRs (where possible from self-consistent datasets) for use as a general reference. In this poster we present the current state of the database, updated with new measurements from radio surveys. We also provide our guidelines for SNR nomenclature, identification, and classification; as well as some

preliminary statistics for SNR types, diameters, radio and X-ray luminosities, and other useful indicators. The authors thank NASA's LTSA grant NNX08AM54G for support of this long-term project.

256.30

Infrared Spectral Mapping of Supernova Remnants: II. N49: A First Look

Michael Johnson¹, R. Williams¹, Z. Edwards¹

¹Columbus State University.

Exhibit Hall

The infrared emission in supernova remnants (SNRs) is a complex combination of gas-phase line emission, PAH-band emission, and thermal continuum from dust, as well as less prominent source. This presents the observer with both challenges and opportunities. In this poster we take a look at some of the first results from our infrared spectral mapping on the SNR N49 in the Large Magellanic Cloud. We will briefly discuss the data reduction and background subtraction for our maps and spectra for this remnant, and will highlight areas on and off the SNR showing relative line versus continuum emission. We will also display narrow band maps in specific molecular and ionic lines, and use line ratio analysis and blackbody and dust fits on selected regions to infer physical properties of hot gas and dust within N49.

256.31

An Atypical Neon Rich Type 1-a SNR in the SMC: an Astronomical Vegas Strip?

Quentin Roper¹, R. L. McEntaffer¹

¹University of Iowa.

Exhibit Hall

Supernova Remnant (SNR) 0104-72.3 is a highly asymmetric SNR discovered in the Small Magellanic Cloud. Its metallicity-poor environment led Hughes and Smith et al. (1994) to conclude that 0104-72.3 was formed by a Type 2 supernova. However, in a recent *Chandra* observation, Fe-L emission was identified in the spectrum of 0104-72.3, and, when combined with its asymmetry, led Park et al. to conclude that 0104-72.3 was formed by a Type 1-a supernova. We, through this presentation, will support the findings of Park et al., and also introduce new results in the discovery of Ne IX ejecta emission, which is inconsistent with many of the extant explosion models of Type I-a supernovae. We will discuss the atypical nature of this SNR's birth, including the possibility of a doubly-degenerate merger of C-O white dwarves, or the possibility that this was formed by accretion onto an O-Ne-Mg white dwarf.

256.32

Supernova Remnants, Binaries And Diffuse X-ray Emission From NGC4449

Knox S. Long¹, W. P. Blair², P. F. Winkler³

¹STScI, ²JHU, ³Middlebury College.

Exhibit Hall

NGC4449 is a relatively nearby Magellanic irregular galaxy, which houses a 50-100 year old remnant of an undetected core-collapse supernova, which remains the brightest observed X-ray supernova remnant (SNR) in the Universe. The galaxy also shows diffuse X-ray emission from outflowing gas powered by supernovae and stellar winds from an active starburst. Here we discuss new Chandra observations of the SNR and the galaxy, as well as new optical spectra of the SNR. We describe the time-evolution of the X-ray SNR, characterize the approximately 25 discrete X-ray sources associated with the galaxy, and discuss the properties of the soft X-ray emission from the outflow.

Multi-Wavelength Observations of the Supernova Remnant Populations in the Nearby Spiral Galaxies IC 342 and NGC 4258

Thomas Pannuti¹, L. Chomiuk², C. K. Grimes¹, W. D. Staggs¹, J. M. Tussey¹, S. Laine³, E. Schlegel⁴ ¹Morehead State University, ²National Radio Astronomy Observatory/Harvard-Smithsonian CfA, ³Spitzer Science Center/Caltech, ⁴University of Texas-San Antonio. Exhibit Hall

Supernova remnants (SNRs) are intimately tied to many crucial processes associated with the interstellar medium of galaxies, such as the acceleration of cosmic-ray particles and the deposition of vast amounts of kinetic energy and chemically-enriched material. Well-known observational challenges in the study of SNRs located in the Milky Way Galaxy (for example, formidable extinction along Galactic lines of sight and considerable uncertainties in the distances to these sources) have motivated searches for SNRs in nearby galaxies at such characteristic wavelengths as X-ray, optical and radio. These searches have revealed a considerable number of SNRs and led to new insights into their properties, but the SNR populations in only a handful of nearby galaxies have been adequately surveyed at multiple wavelengths. To help remedy this situation, we are conducting a multi-wavelength study of the SNR population of selected nearby galaxies. To illustrate our work, we

present the results of studies of the SNR population in two nearby spiral galaxies, IC 342 and NGC 4258. Our results draw upon the analysis of pointed archival radio and X-ray observations of these two galaxies. Initial results will be presented and discussed.

257

Emerging Results on an Extreme Binary, Epsilon Aur Poster Session *Exhibit Hall*

257.01

Campaign Photometry During The 2010 Eclipse Of Epsilon Aurigae Jeff Hopkins¹, R. E. Stencel² ¹*HPO Soft,* ²*Denver University. Exhibit Hall*

Epsilon Aurigae is a long period (27.1 years) eclipsing binary star system with an eclipse that lasts nearly 2 years, but with severe ambiguities about component masses and shape. The current eclipse began on schedule in August of 2009. During the previous, 1982-1984 eclipse, an International Campaign was formed to coordinate a detailed study of the system. While that Campaign was deemed successful, the evolutionary status of the star system remained unclear. Epsilon Aurigae has been observed nearly continuously since the 1982 eclipse. The current Campaign was officially started in 2006. In addition to a Yahoo forum we have a dedicated web site and more than 18 online newsletters reporting photometry, spectroscopy, interferometry and polarimetry data. High quality UBVRIJH band photometric data since before the start of the current eclipse has been submitted. We explore the color differences among the light curves in terms of eclipse phases and archival data. At least one new model of the star system has been proposed since the current Campaign began: a low mass but very high luminosity F star plus a B star surrounded by a debris disk. The current eclipse and in particular the interferometry and spectroscopic data have caused new thoughts on defining eclipsing variable star contact points and phases of an eclipse. Second contact may not be the same point as start of totality and third contact may not be the same point as the start of egress and end of totality. In addition, the much awaited mideclipse brightening may or may not have appeared. This paper identifies the current Campaign contributors and the photometric data. This work was supported in part by the bequest of William

Herschel Womble in support of astronomy at the University of Denver, by NSF grant 1016678 to the University of Denver.

257.02

Analysis of Epsilon Aurigae light curve from the Solar Mass Ejection Imager

John Clover¹, B. V. Jackson¹, A. Buffington¹, P. P. Hick¹, B. Kloppenborg², R. Stencel² ¹University of California, San Diego, ²University of Denver. Exhibit Hall

The Solar Mass Ejection Imager (SMEI) was launched aboard the Coriolis spacecraft in 2003. It is equipped with 3 CCD cameras to measure the brightness of Thomson-scattered electrons in the heliosphere. Each CCD images a strip of the sky that is 3°x60°. The three cameras are mounted on the satellite with their fields of view aligned end-to-end so that SMEI sweeps nearly the entire sky each 102 minute orbit. SMEI has now accumulated stellar time series for about 5700 bright stars, including epsilon Aurigae, for each orbit where data is available. SMEI data provide nearly year-round coverage of epsilon Aurigae. The baffled SMEI optics provide more accurate photometric data than ground-based observations, particularly at mid-eclipse when epsilon Aurigae is close to the Sun. We present an analysis of the brightness variations of the epsilon Aurigae system, before and during the eclipse. The University of Denver participants are grateful for support under NSFgrant 10-16678 and the bequest of William Hershel Womble in support of astronomy at the University of Denver.

257.03

Interferometric Images Of The Transiting Disk In The Epsilon Aurigae System

Brian K. Kloppenborg¹, R. Stencel¹, J. D. Monnier², G. Schaefer³, M. Zhao⁴, F. Baron², H. McAlister⁵, T. ten Brummelaar⁵, X. Che², C. Farrington⁵, E. Pedretti⁶, P. Sallave-Goldfinger⁵, J. Sturmann⁵, L. Sturmann⁵, N. Thureau⁷, N. Turner⁵, S. Carroll⁸

¹University of Denver, ²University of Michigan, ³Georgia State, ⁴Jet Propulsion Laboratory, ⁵Georgia State University, ⁶SUPA, University of St. Andrews, United Kingdom, ⁷University of St. Andrews, United Kingdom, ⁸California Institute of Technology.

Exhibit Hall

We have been using the CHARA Array with the MIRC beam combiner to obtain the first-ever interferometric observations of the enigmatic binary, epsilon Aurigae. The first two in-eclipse images, obtained in 2009, prove that the eclipsing body is a thin, opaque disk of material akin to transitional or debris disks. From these data we have derived a mass ratio that shows the F-type star is $3.6 \pm 0.7 \text{ M} \odot$, making it the less massive component in the system and thus not a high-mass supergiant as was classically believed. Four additional observations were scheduled in 2010. In this work we present reconstructed images from all epochs using two new image reconstruction algorithms, SQUEEZE and GPAIR. We discuss the progress towards our goals: to determine the evolutionary status of the components in the binary; and define the composition, density, and temperature structure of the disk. The CHARA Array, operated by Georgia State University, was built with funding provided by the National Science Foundation, Georgia State University, the W. M. Keck Foundation, and the David and Lucile Packard Foundation. This research is supported by the National Science Foundation as well as by funding from the office of the Dean of the College of Arts and Science at Georgia State University. MIRC was supported by the National Science Foundation. The University of Denver participants are grateful for support under NSF grant 10-16678 and the bequest of William Hershel Womble in support of astronomy at the University of Denver.
257.04

Spectroscopic Wonders During The 2010 Eclipse Of Epsilon Aurigae

Robin Leadbeater¹, C. Buil², T. Garrell³, S. Gorodenski⁴, J. Hopkins⁵, B. Mauclaire⁶, J. Ribeiro⁷, L. Schanne⁸, O. Thizy⁹, R. Stencel¹⁰

¹Three Hills Observatory, ²Castanet Tolosan Observatory, France, ³Observatoire de Foncaude, France, ⁴Blue Hills Observatory, ⁵Hopkins Phoenix Observatory, ⁶Observatoire du Val de l'Arc, France, ⁷Observatorio de Instituto Geografico de Exercito, Portugal, ⁸Voelklingen Observatory, Germany, ⁹Shelyak Instruments, France, ¹⁰University of Denver.

Exhibit Hall

Remarkable spectroscopic coverage is reported of the 2009-2011 eclipse of the enigmatic binary, epsilon Aurigae. Due to the availability of new spectrographs and digital detectors, unprecedented monitoring by a network of observers using small telescopes has revealed a number of details and surprises that must be taken into account in any updated model for the over-luminous F star and the dark disk companion, recently detected interferometrically. Over 400 spectra were obtained during 2007 to 2010 (pre eclipse to post mid eclipse). They include R ~12000 echelle spectra giving broad coverage from 4300-7000A and detailed spectra at R ~17000-25000 covering the Sodium D, Hydrogen alpha and Potassium 7699A line regions. Evidence of the eclipsing body was first seen in the 7699A line profile 83 days before photometric first contact. During ingress, the strength of this line increased in a stepwise fashion suggesting structure in the disc. During the first half of totality, the line strength trend deviated from that seen during the last eclipse. Radial velocity measurements of the 7699A line during ingress are consistent with the disc material orbiting a central object of 5.3 solar masses. Changes in the Hydrogen alpha line profile during totality reveal the presence of a foreground emission source centered at the systemic radial velocity. A small transient emission line has been seen at 6604A on two occasions during the eclipse. This work was supported in part by the bequest of William Herschel Womble in support of astronomy at the University of Denver, and by NSF grant 1016678 to the University of Denver. We are grateful for the assistance of the epsilon Aurigae spectral monitoring team at Apache Point Observatory (W. Ketzeback, J.Barentine, et al.) and all observers participating in the international eclipse monitoring campaign.

257.05

Optical and NIR Spectroscopy of ε Aurigae at Apache Point Observatory, the First Half of the Eclipse William F. Ketzeback¹, J. Barentine², R. Leadbeater³, R. McMillan¹, J. Dembicky¹, G. Saurage¹, J. Huehnerhoff¹, S. Schmidt⁴, S. Hawley⁴, G. Wallerstein⁴, J. Coughlin⁵, D. York⁶

¹Apache Point Observatory, ²UT Austin, ³Brititsh Astronomical Association, United Kingdom, ⁴University of Washington, ⁵New Mexico State University, ⁶University of Chicago.

Exhibit Hall

Epsilon Aurigae (ϵ Aur), first confirmed as a variable in 1821, is an eclipsing binary star system with a period of 27.1 years, one of the longest known. The primary, a pulsating F supergiant star with a variability out of eclipse of approximately 60 days and possible overtones of hundreds of days, is orbited by the secondary, a B-star enveloped by an enormous, cool, spectrally gray disk producing no evident wavelength dependence to the light output variations. The eclipse lasts for over 700 days; the current eclipse began first contact in July, 2009, and August 4, 2010 marked the estimated midway point of the eclipse. Although the components of the system have now been identified, much is still unclear such as the origin, composition and structure of the disk. Modern digital spectroscopy of bright stars not only enables asteroseismology and planetary detection, but the eclipsing binary epsilon Aurigae is an unusual case in which precise spectroscopic study of the now transiting dark disk is enabled. At Apache Point Observatory, our team has conducted high-resolution optical and NIR spectroscopic monitoring of this mysterious eclipsing system since February, 2009. We present major changes in the spectra attributable

to the disk from the first half of the eclipse in the 0.4 - 2.2 μ m range using ARCES, an optical echelle spectrograph ($\lambda/\Delta\lambda$ =31,500), and Triplespec, a NIR cross-dispersed spectrograph ($\lambda/\Delta\lambda$ =3500), on the ARC 3.5-meter telescope.

257.06

Epsilon Aurigae - Intriguing Changes with Phase R. E. M. Griffin¹

¹*Herzberg Inst. of Astrophysics, Canada. Exhibit Hall*

Epsilon Aurigae has baffled generations of astrophysicists, and the need to hold a Special Session about this system arises from the depth and persistence of our bafflement. Although the obvious (dominant) star - an early-F supergiant - is partially eclipsed during its 27-year period such that the overall brightness drops by ~1 magnitude in V, the spectrum of the system does not change. That fact is what has made epsilon Aurigae traditionally famous. Moreover, the dark object that moves in front must have gigantic proportions. However, it is not actually true to say that the spectrum does not change. It is still recognizeably an early-F supergiant but it changes significantly during eclipse ingress and egress, in ways that provide invaluable information about the mysterious body that was in front throughout 2010 (and still is). Nothing is yet known regarding the properties or constancy of the dark body, and to that end we have sought new information from the long series of spectra in heritage (photographic) archives. The two richest sets of high-dispersion spectra are from the DAO, dating back to 1972, and Mount Wilson, dating back to 1929, offering resolving power of the order of 50,000 and including both blue and red spectral regions. While both sets cover the 1983 eclipse (as do many independent photometric datasets), the Mount Wilson spectra are unique in their rich cover of the 1956 eclipse, and include some of the 1929 event. We have digitized about 300 plates, and are analysing the information by comparing spectra at all orbital phases with new CCD ones as far as possible. The poster will summarize the findings, which will be described in greater detail during the Special Session on epsilon Aurigae on Tuesday January 11.

257.07

Hubble Space Telescope Ultraviolet Observations of Epsilon Aurigae

Steve B. Howell¹, R. E. Stencel², D. W. Hoard³

¹NOAO, ²University of Denver, ³Spitzer Science Center. Exhibit Hall

We present the initial observations from our multi-epoch COS program, with three planned observations of Epsilon Aurigae. The first observation was obtained on 2010 Sept 1st, shortly after mid-eclipse. The remaining two are scheduled for mid-December 2010, during totality, and during egress in mid-April 2011. Epsilon Aurigae is a complex binary system consisting of a post-AGB F giant orbited by a B star encircled by a large dust cloud. The B star dominates the spectral energy distribution only in the far-UV portion of the spectrum. We use our 900-2050A COS results to 1) model the B star yielding its Teff and log g, 2) search for warm circumbinary material, and 3) confirm the nature of the B star as input to our recent work providing the most detailed SED model yet developed for Epsilon Aurigae (http://adsabs.harvard.edu/abs/2010ApJ...714..549H).

257.08

Ring-like Structures Around Epsilon Aurigae Companion

Sally Seebode¹, S. B. Howell², D. Drumheller³, D. Stanford³, D. W. Hoard⁴, R. E. Stencel⁵ ¹San Mateo High School, ²NOAO, ³College of San Mateo, ⁴Spitzer Science Center, ⁵University of Denver. Exhibit Hall

Epsilon Aurigae, a 27.1 year eclipsing binary, consists of a post-AGB F giant and a main sequence B star. The B star is surrounded by a large dust disk. Our team obtained and analyzed over 60 red(5800 - 6600A) and blue (3800 - 4600A) spectra using the College of San Mateo (CSM) Meade 8" telescope, with SBIG SGS spectrograph, and the Kitt Peak National Observatory Coude feed spectrograph. Measurements of the equivalent widths of a number of elements indicate density variations in the dust disk surrounding the companion B star of epsilon Aurigae. This disk substructure is similar to that suggested by Leadbeater and Stencel (2010, http://arxiv.org/abs/1003.3617v2) and agrees with the theoretical rings proposed by S. Ferluga (1990, A&A, 238,270) based on observations of the 1982 eclipse. Our data was collected and analyzed from February 2009 (pre-eclipse) through April 2010. We are continuing to obtain spectroscopic observations through eclipse and egress in order to provide further data and evidence for the possible ring structure in the dusty disk. This study is part of the NASA/IPAC Teacher Archive Research Project (NITARP).

257.09

Infrared Studies of Epsilon Aurigae in Eclipse 2010

Robert E. Stencel¹, B. Kloppenborg¹, R. Wall¹, S. Howell², D. Hoard³, J. Rayner⁴, S. Bus⁴, A. Tokunaga⁴, M. Sitko⁵, R. Russell⁶, D. Lynch⁶, S. Brafford⁷, H. Hammel⁸, B. Whitney⁸, G. Orton⁹, P. Yanamandra-Fisher⁹, J. Hora¹⁰, W. Hoffman¹¹, A. Skemer¹¹

¹Univ. of Denver, ²NOAO, ³IPAC, ⁴IRTF, ⁵Univ. Cincinnati, ⁶The Aerospace Corp., ⁷Esq., ⁸Space Science Institute, ⁹JPL, ¹⁰Harvard Univ., ¹¹Univ. Arizona.

Exhibit Hall

We report a series of observations of the enigmatic long period eclipsing binary epsilon Aurigae during its eclipse interval 2009-2011, using near-infrared spectra & amp; photometry obtained with SpeX/IRTF, Spitzer/IRAC, mid-infrared data with BASS on IRTF & amp; AEOS, MIRSI on IRTF and MIRAC4 on MMT, along with MIRSI on IRTF and MIRAC4 on MMT & amp; Denver's TNTCAM2 at WIRO, and an Optec SSP-4 J& amp; H photometer at Mt.Evans Observatory. The objective of these observations include: (1) confirm the appearance of CO absorption bands at and after mid-eclipse, due to the dark disk, and (2) seek evidence for any mid-infrared solid state spectral features from particles in the disk, seen during different portions of total eclipse. The results to date show that the infrared eclipse is less deep than the optical one, and the implied disk temperature has begun to increase from 550K toward 1100K as eclipse progresses past midpoint and heated portions of the disk come into view. Material properties of the disk are consistent with large particles. This work was supported in part by the bequest of William Herschel Womble in support of astronomy at the University of Denver, by NSF grant 1016678 and JPL RSA 1414715 to the University of Denver, by NASA ADP grant NNX09AC73G to the University of Cincinnati, by The Aerospace Corporation's Independent Research and Development Program.

258 *Star Formation* Poster Session *Exhibit Hall*

258.01

Mass Functions in Fractal Clouds: The Role of Cloud Structure in the Stellar Initial Mass Function Bruce Elmegreen¹, M. Shadmehri²

¹IBM Research Div., ²National University Ireland, Ireland. Exhibit Hall

The possibility that the stellar initial mass function (IMF) arises mostly from cloud structure is investigated with fractal Brownian motion (fBm) clouds that have power-law power spectra. An fBm cloud with a realistic projected power spectrum slope of beta=2.8 is found to have a mass function for clumps exceeding a threshold density that is a power-law with a slope of alpha=2.35, the same as in the Salpeter IMF. Any hierarchically structured cloud has a clump mass function with about the same slope. This result implies that turbulent interstellar clouds produce dense substructure with the observed prestellar core mass function built in from the start. Details of the clump formation processes are not critical. The conversion of clumps into stars involves a second step. A one-to-one correspondence between clump mass and star mass is not necessary to convert the clump mass spectrum into an IMF with the same power-law slope. As long as clumps have an internal stellar IMF from sub-fragmentation, protostellar accretion, coalescence and other processes, and the characteristic mass for this internal IMF scales with the clump mass, then the IMF slope above the minimum characteristic mass will equal the clump mass slope. A detailed review of IMF models illustrates the prominence of cloud structure as a major component in a wide class of theories. Tests are proposed to determine the relative importance of cloud structure and competitive accretion in the IMF.

258.02

Characterizing Potential Precursors to Massive Stars with Hi-GAL

Cara Battersby¹, J. Bally¹, A. Ginsburg¹, Hi-GAL Consortium

¹University of Colorado Boulder.

Exhibit Hall

In the past decade, compelling evidence has emerged that suggests Infrared Dark Clouds (IRDCs) may be the precursors to stellar clusters and therefore massive stars. Detection of an IRDC, however, requires that the cloud be on the near-side of a bright mid-IR background, while dust continuum observations are subject only to a sensitivity limit. We present full dust temperature and column density maps in the Hi-GAL Science Demonstration Phase fields based on background-subtracted graybody fits to SPIRE and PACS data. We compare the physical properties of IR-dark vs. IR-bright regions and examine how these physical properties vary with the presence of different star formation tracers. We identify the dust temperatures and column densities that characterize IRDCs and explore the population of dust continuum sources that are not IRDCs. If IRDCs truly are the precursors to massive stars and clusters it is essential to understand their physical properties on a Galactic scale, which requires a sample that is unbiased by viewing angle. We use Hi-GAL to expand this sample of potential proto-clusters to cold, high-column sources without a background to absorb.

258.03

Formaldehyde Densitometry of Dust Clumps: The Shapes and Densities of Massive Star Forming Regions

Adam Ginsburg¹, C. Battersby¹, B. Zeiger¹, J. Darling¹, J. Bally¹

¹University of Colorado.

Exhibit Hall

Millimeter-emitting dust clumps in the Galactic Plane are thought to be high-density condensations within Giant Molecular Clouds and signatures of high mass star forming regions. We have observed a sample of these objects in the formaldehyde 2 and 6 cm transitions in order to precisely measure their volume densities. We present selected results from our ongoing survey. A sample of ultracompact HII regions are observed to have a variety of distinct velocity-density profiles, some of which may be indicative of infall. A degree scale map of W51 in the 2 cm formaldehyde transition suggests that this million-solar-mass GMC may be thin in one dimension (pancake-like). The survey will eventually measure densities of 1.1 mm dust clumps covering a full range of evolutionary states of the molecular gas, from pre-star-forming to evolved compact HII regions.

258.04

The Evolution of Circumstellar Disks Surrounding Intermediate Mass Stars: IC 1805

Luisa M. Rebull¹, S. Wolff², S. Strom²

¹*Caltech,* ²*NOAO.*

Exhibit Hall

We report the results of a study of the intermediate and high mass stars in the young, rich star-forming complex IC 1805, based on a combination of optical, near-infrared, and mid-infrared photometry, and classification spectra. These data provide the basis for characterizing the masses and ages for stars more massive than ~2 Msun and enable a study of the frequency and character of circumstellar disks associated with intermediate- and high-mass stars. Optically thick accretion disks among stars with masses 2 < M/Msun <4 are rare (~2% of members) and absent among more massive stars. A larger fraction (~10%) of stars with masses 2 < M/Msun < 4 appear to be surrounded by disks that have evolved from the initial optically thick accretion phase. We identify four classes of such disks. These classes are based on spectral energy distributions (SEDs) of excess emission above photospheric levels: disks that are (1) optically thin based on the magnitude of the observed excess emission from 2 to 24 um; (2) optically thin in their inner regions (r< 20 AU) and optically thick in their outer regions; (3) exhibit empty inner regions and optically thick outer regions. We discuss, and assess the merits and liabilities of, proposed explanations for disks exhibiting these SED types and suggest additional observations that would test these proposals.

258.05

Role of Shocks and Cavity Walls in Massive Star Envelopes

Sandy Doty¹, S. Doty², S. Bruderer³, A. Bruce², L. Kristensen⁴, R. Visser⁵, E. van Dishoeck⁴ ¹Ohio University of Lancaster, ²Denison University, ³ETH Zurich, Switzerland, ⁴Leiden University, Netherlands, ⁵University of Michigan.

Exhibit Hall

The formation of massive stars is often associated with jets and/or strong outflows. These outflows often produce a visible cavity in the surrounding envelope. Previous work has shown that the direct irradiation of the cavity wall by UV photons from near the protostellar surface has a significant and measurable effect on the observed spectrum. In particular, significant CO+, and highly excited molecular lines (e.g. of CO and H2O) are both seen and predicted. However, while UV photons explain the

observed CO+ spectrum, they appear to be insufficient alone to explain the high-J CO spectrum seen by Herschel. Shocks from the jet and outflow impinging on the cavity wall may provide sufficient extra local heating and material reprocessing to explain the high-J emission that is observed. As a result, we model the effect of shocks on the outflow cavity wall. By explicitly calculating the local physical conditions (including temperature, density, and velocity structures), we then determine the chemical structure of the envelope + cavity walls. Utilizing a radiative transfer model allows us to simulate the observed spectrum for comparison with observations. We find that shocks play a significant role in the case studied.

258.06

Chemical Evolution of Collapsing Clouds in Massive Star Formation

Kris Oman¹, S. Doty¹, M. Krumholz²

¹Denison University, ²University of California Santa Cruz. Exhibit Hall

The process of massive star formation is not well understood. Recent work in large scale radiation

hydrodynamical simulations have strongly suggested that radiation pressure can play an important role in opening cavities through which energy can be released, thus avoiding the problems of high radiation pressure supressing massive star formation. As a result, this pressure valve allows for the direct accretion of matter, and formation of massive stars. While these models include significant microphysics, it is important that predictions be made that allow the models to be compared with observations. Toward that end, we have undertaken a study of the chemistry in one of these collapsing cloud models. The chemical model involves the application of a large gas-phase and grain surface chemistry to the dynamical structure, including the effects of density, temperature, and radiation field. We present maps of H2, CO, and other molecular abundances as functions of space and time, as well as consider the resulting observational consequences of these results.

258.07

Mid-Infrared Imaging of Massive Star Formation in Cygnus-X

Joseph L. Hora¹, H. A. Smith¹, R. L. Doering², Spitzer Cygnus-X Survey Team ¹Harvard-Smithsonian CFA, ²University of Wisconsin-Madison.

Exhibit Hall

Cygnus-X is the richest known concentration of massive protostars and the largest OB associations in the nearest 2 kpc, and thus is a unique laboratory to study the poorly constrained early stages of massive star formation. We have conducted an unbiased survey of the 24 square degree Cygnus-X region with Spitzer/IRAC and MIPS to study the high-mass and associated low-mass star formation. Spitzer, however, is unable to resolve some of the more complex regions, and some sources are bright enough to saturate IRAC and MIPS in the shortest integration times. We present here initial results from follow-up 8 - 24 micron imaging obtained at the IRTF of a sample of massive star forming regions selected from our Spitzer survey. The higher spatial resolution at the IRTF allows us to resolve multiple sources and determine the distribution of flux between the various protostars and emission from the ISM in their vicinity. We can also obtain fluxes for regions that are saturated in the Spitzer data. The sample includes objects with a range of masses and at various stages of evolution. These data, along with the Spitzer images and IRS spectra, will enable us to determine the properties of these massive stars and to examine the effects that they are having on their surroundings, including outflows into the nearby ISM and in triggering further generations of star formation.

258.08

Modeling Disks Around Massive Protostars

Jeffrey M. Cochran¹, S. Doty¹, J. Lacy²

¹Denison University, ²University of Texas.

Exhibit Hall

While the process of massive star formation is uncertain, recent radiation hydrodynamical models suggest that massive stars could form through accretion. As part of this process, it is suggested that a massive protostellar disk could be formed around the protostar. Driven by this possibility, we explore the potential signatures of the existence of such disks. We thus have constructed and present a self-consistent model of a high-mass protostellar disk. In this case, we apply the disk to the well-studied region NGC 7538IRS9. In this model, we solve for the spatial structure of the temperature, density, and radiation field. With these inputs, we solve for the chemistry throughout the disk, including CO, CS, HCO+, H2O, OH, and C2H2. We then create simulated observations at different transitions and source inclinations. When compared with actual data, radiation from these four molecules provide potential constraints about the existence, as well as the structure and orientation of a disk.

258.09

Models Of Gas-grain Chemistry In The Infalling Envelope Of Afgl 2591

Steven D. Doty¹, R. Visser², E. van Dishoeck³, J. Tan⁴

¹Denison Univ., ²University of Michigan, ³Leiden University, Netherlands, ⁴University of Florida. Exhibit Hall

While the processes of low-mass star formation are relatively well-understood, the same cannot be said for the processes involved in massive star-formation. It has been suggested that turbulent support may play an important role in the collapse of clouds to form massive stars. Studies of the evaporation of ices and ensuing gas-phase chemical evolution in these regions suggests that predictions from a turbulently supported cloud are consistent with existing observations. In this study, we extend our previous work to explicitly include grain-surface chemistry. We consider both adsorption and desorption, as well as chemistry on the grain surface. Photoprocessing of the ices is considered as well. The resulting gas and grain-surface chemical evolution is then applied to a thermally and dynamically evolving envelope, while allowing the protostar to grow in time. We present the results of these models to the well-studied source AFGL 2591. Simulated observations are also produced for comparison against existing and upcoming observational data.

258.10

The Turbulent Fragmentation Origin of Low-Mass Binary Star Systems

Stella Offner¹, K. M. Kratter¹, C. D. Matzner², M. R. Krumholz³, R. I. Klein⁴

¹Harvard-Smithsonian Center for Astrophysics, ²University of Toronto, Canada, ³U.C. Santa Cruz, ⁴UC Berkeley.

Exhibit Hall

Using self-gravitating, radiation-hydrodynamic

simulations, we compare turbulent fragmentation

and disk fragmentation as avenues for forming low-mass binary systems.

We employ two dimensionless parameters to characterize the infall rate onto

protostellar systems, describe disks'

susceptability to fragmentation, and place limits on protostellar

system multiplicity.

While protostellar disks are predominatly stable in the presence of

radiative feedback, purely hydrodynamic systems exhibit fundamentally

different parameters and are strongly susceptible to disk fragmentation. Consequently, we find that turbulent fragmentation, occuring

on thousand AU scales, is the more common mode of fragmentation and is likely responsible for producing most low-mass binary systems. Although fragmentation in young embedded protostellar disks cannot be directly imaged, turbulent fragmentation on these scales is potentially observable.

258.11

New Detections Of Werner-band Molecular Hydrogen Lines In Classical T Tauri Stars With Hst/cos Hao Yang¹, J. L. Linsky¹, K. France²

¹JILA, University of Colorado at Boulder and NIST, ²CASA, University of Colorado at Boulder. Exhibit Hall

We present identification of atmoic and molecular hydrogen lines shortward of 1200 A in the far ultraviolet in the spectra of two classical T Tauri stars, DF Tau and V4046 Sgr. These lines have not been observed in a protostellar/protoplanetary envelope and such observations have just recently become possible, thanks to the high sensitivity and very low background noise of the Cosmic Origins Spectrograph (COS) newly installed on the Hubble Space Telescope (HST). The molecular hydrogen lines below 1250 A are mostly Werner band lines, and we discuss their photoexcitation routes. A comparison of the spectra indicates that the observed lines are not common to all disks, possibly due to differences in disk inclination, ground-state H2 population, and shape of the pumping radiation field in the two objects. This work is supported by a NASA grant to the University of Colorado.

258.12

Fitting Outflow Models to Millimeter Molecular Line Observations of L1228 and L1527

Christopher H. De Vries¹, S. Terebey², H. G. Arce³, A. Isella⁴

¹California State University, Stanislaus, ²California State University, Los Angeles, ³Yale University, ⁴California Institute of Technology.

Exhibit Hall

We present a physical outflow model which minimizes free parameters while maintaining the ability match a wide variety of millimeter and submillimeter observations of molecular line emission observed in protostellar sources. We fit this model to ¹²CO (J=1-0) and ¹³CO (J=1-0) observations of L1228 and L1527 in order to investigate the physical properties of the outflows that best match the observations. The model includes radiative transfer calculations which allow us to investigate relative abundances of molecular species and their excitation conditions. Certain simplifying assumptions are made in order to reduce the free parameter space. The impact of these decisions are discussed and evaluated in the context of these well-studied sources. We explore the use of this model in obtaining parameters such as the momentum and kinetic energy, which are often calculated from observations.

258.13

Visualization and Analysis of Synthetic Observations of Embedded Protostellar Outflows

Michelle A. Borkin¹, S. S. R. Offner², E. J. Lee³, H. G. Arce⁴, A. A. Goodman²

¹Harvard University, ²Harvard-Smithsonian Center for Astrophysics, ³University Of Toronto, Canada, ⁴Yale University.

Exhibit Hall

We present 3D visualizations used for the analysis and exploration of synthetic observations and in comparing synthetic with real observational data cubes. By comparing synthetic observations (i.e., *position-position-velocity* cubes) to the original simulation output (i.e., *position-position-position-position*)

utilizing 3D visualization techniques we are able to more effectively and efficiently compare these types of data, in particular kinematic structures such as outflows. We investigate simulations performed with the ORION adaptive mesh refinement (AMR) three-dimensional gravito-radiation-hydrodyanics code, which follow the collapse and evolution of protostars with outflows down to AU size scales. The ¹²CO synthetic observations are produced using MOLLIE, a molecular line radiative transfer code. Comparing the 2D column maps, 3D *p-p-p* cubes, and synthetic ¹²CO *p-p-v* cubes allows us to connect real and observed physical structures and enhance the interpretation of astronomical data cubes.

258.14

A Narrow-band Survey of Protostellar Shock Activity

Meredith M. Drosback¹, R. Indebetouw¹

¹University of Virginia.

Exhibit Hall

Energetic outflows are a ubiquitous signpost of star formation, observed in young stars of all masses. In studies of the early stages of star formation, we strive both to understand the mechanical and chemical properties of gas within an outflow, and to characterize outflow interactions with the dense clouds in which they are embedded. To develop a complete model of the interactions between protostar, outflow, and natal molecular cloud, surveys of entire star forming clouds as well as detailed studies of individual outflows are required. We have conducted a near-infrared protostellar shock survey of 35 star-forming regions in the Galaxy, including both isolated, individual outflows as well as larger molecular clouds containing multiple outflows. We imaged these regions in near-infrared narrow-band emission lines of molecular hydrogen, [FeII], and Paschen beta with the refurbished 2MASS camera on the Steward Observatory 61-inch Kuiper telescope. In addition, we have obtained moderate resolution (R=3500) near-infrared spectra (using TripleSpec at the Apache Point Observatory) for some of the individual outflows. We use the complementary near-infrared spectroscopic and imaging data to characterize the physical properties of each outflow, including excitation temperatures, emission line velocities, and energetics, and to describe the feedback these outflows may have on their natal clouds.

258.15

A Spitzer Imaging Survey of Bright-Rimmed Clouds

Lori Allen¹, D. Peterson², S. Ballard³

¹NOAO, ²Smithsonian Astrophysical Observatory, ³Harvard-Smithsonian Center for Astrophysics. Exhibit Hall

We present results from a suvey of 32 bright-rimmed clouds by the Spitzer Space Telescope. The sample was compiled from the lists of Sugitani, Fukui & amp; Ogura (1991) and Sugitani & amp; Ogura (1994), and each region was imaged with IRAC (3.6, 4.5, 5.8 and 8 micron) and with MIPS (24 and 70 micron). For each cloud, we identify and (based on spectral energy distributions) classify its YSOs. Where 70 micron sources are detectable, we calculate bolometric luminosities and temperatures, and compare these with other evolutionary indicators.

258.16

Young Clusters Forming in Isolation

Dawn E. Peterson¹, L. Allen², R. Gutermuth³, T. Bourke¹

¹Harvard-Smithsonian CfA, ²NOAO, ³University of Massachusetts at Amherst.

Exhibit Hall

We present preliminary results from a study of a large sample of Bok globules that have been observed with the NASA Spitzer Space Telescope. We identify and classify young stellar objects using Spitzer and near-infrared 2MASS photometry, and will present the ratio of Class I to Class II YSOs in each of the regions. In addition, near-infrared extinction maps will be presented. The stellar populations will be

used, along with the known gas masses of these clouds to estimate the fraction of the gas from a molecular cloud that typically ends up as stars. The initial conditions for the formation of a single star, binary or cluster of stars can be constrained, and with an estimate of the age from theoretical models, the time it takes a star (or a cluster of stars) to form can also be constrained, as well as the timescales for the various evolutionary states. Bok globules are unique because they are simple environments, free from the confusing effects of winds and external turbulence that are often seen in young clusters embedded within larger, star-forming complexes. As part of our study, we will compare these simple structures, which span a wide range of evolutionary states, with more complex bright-rimmed clouds, which are strongly influenced by nearby O and B stars, ultimately studying the role of environment in star formation.

258.18

Cygnus OB2 - Archaeology Of Our Closest Massive Star Factory Erik Van Der Veen $^{\rm 1}$

¹Harvard-Smithsonian,CfA.

Exhibit Hall

Cygnus OB2 is the nearest example of a massive star-forming region, at only 1.45kpc. Despite its status and importance, we still lack a basic understanding of this complex. Practically all of its 50+ O-type stars and some of its B-type stars have been scoped, but low-mass members remain poorly studied. An extensive set of new spectra collected using the FAST and HectoSpec instruments at the Fred Lawrence Whipple Observatory is allowing for a much more detailed study of the association.

Optical spectra of pre-main sequence objects, vital in developing our global understanding of star formation and the products thereof, are being analyzed in order to characterize masses and velocities of individual objects within the region. The level of reddening of the spectra is first identified, providing a more reliable estimate of spectral type than photometry alone, and from which stellar mass and temperatures are derived. Velocities are then obtained via cross-correlation and line centroiding techniques. Combining these two results will map out the distribution of velocities as a function of stellar mass. The end goal of this study is to understand the dynamics and boundedness of the cluster, and to diagnose the presence of any sub-clustering and mass segregation. In this way, Cygnus OB2 is poised to become a stepping stone with which to extend our detailed understanding of Gould Belt star forming regions down to the lowest mass stars to much more massive clusters and starbursts.

258.19

The Structure of the Large Young Cluster CepOB3b

Robert A. Gutermuth¹, T. Allen², T. Megeath², J. Pipher³, S. Wolk⁴

¹FCAD/Smith College, ²University of Toledo, ³University of Rochester, ⁴Harvard-Smithsonian CfA. Exhibit Hall

We have conducted a detailed characterization of the structure of the CepOB3b young cluster using membership lists derived from space-based (Spitzer mid-IR and Chandra Xray) and ground-based (NEWFIRM near-IR) imaging. We currently estimate the CepOB3b cluster membership at roughly 2500 members; at a distance of 700 pc, CepOB3b is the second nearest large (>1000 members) young cluster after the Orion Nebula Cluster. Recent examination of the Spitzer-identified YSOs has revealed that the Cep B cluster (CepOB3b East) is significantly extended to the west, including a second overdense cluster core (CepOB3b West) near the Cep F molecular cloud core. We present radial and azimuthal surface density profiles of both cluster cores using the improved member list. We also examine the density contrast between the two cores, the intra-core region, and the exterior of the

cluster, in order to constrain the probability that the cluster cores are either physically associated or spatially distinct structures that are associated only by projection.

258.20

The Infrared Properties of Embedded Super Star Clusters: Predictions from Three-Dimensional Radiative Transfer Models

David G. Whelan¹, K. E. Johnson¹, B. A. Whitney², R. Indebetouw¹, K. Wood³ ¹University of Virginia, ²Space Science Institute, ³University of St. Andrews, United Kingdom. Exhibit Hall

The evolution of super star clusters from their formation is not well understood. Constraints on mass and ionizing flux of embedded super star clusters can be found in the literature, but questions concerning physical size, star formation efficiency, and geometry are still largely unanswered. We have run three-dimensional radiative transfer models to study the infrared SEDs and colors of embedded super star clusters to compare to Spitzer, Herschel, and, eventually, JWST data (Whelan et al., submitted). We have found that moderately clumpy dust distributions are inherently degenerate at some wavelengths, making it difficult to discern properties like physical size. However, several passbands can be used to help break these degeneracies and discern between models with different input parameters. We present these diagnostics here in an effort to recover the input parameters from the colors, and to provide the community with a model set for comparison to existing and future infrared observations of embedded super star clusters.

258.21

Analyzing Structure in Star Forming Region AFGL 490 Using Spitzer and Near-IR Photometry Lauren Masiunas¹, R. Gutermuth¹, J. Pipher², P. Meyers³, T. Megeath⁴, L. Allen⁵

¹Smith College, ²University of Rochester, ³Harvard-Smithsonian CfA, ⁴University of Toledo, ⁵NOAO. Exhibit Hall

We present an analysis of expanded Spitzer IRAC and MIPS imaging of the AFGL 490 star forming region and deep SQIID near-IR imaging of its central cluster. Using the combined 1-24 micron photometric catalog derived from these data, we have identified 56 class I and 283 class II young stellar objects (YSOs) forming in this region. We isolated several locally over-dense cluster cores from the spatial distribution of YSOs via analysis of the Minimal Spanning Tree of their positions (Gutermuth et al. 2009). The most populated group contains 215 YSOs (63% of the cluster's members) and has an area of 12 square parsecs. The intermediate mass YSO, AFGL 490, contained within this group, resides 0.73-0.98 parsecs away from the center of the group. We compare these statistics to similarly analyzed clusters (Gutermuth et al. 2009), and briefly explore the mass segregation implications of AFGL 490's position within its cluster.

258.22

Thermal Dust Emission in Infrared Dark Clouds

Scott Phelan¹, E. Chambers¹, F. Yusef-Zadeh¹

¹Northwestern University.

Exhibit Hall

The study of the nucleus of the Milky Way Galaxy (2 x 1.5 degrees of the Galactic center) is an active area of research within the field of astronomy. There is good cause to this activity because our own galactic nucleus is also our best access to any galactic nucleus in the entire universe. The insight that has been gained from such studies of our own Galaxy has been invaluable in characterizing processes that occur within many other similar galaxies. However, star formation within the Galactic nucleus is not one of these well-understood processes. In order to understand the context of star formation within the Galactic nucleus in relation to star formation in the Galactic disk, we study the thermal dust emission

from infrared dark clouds (IRDCs). IRDCs are commonly thought to represent the initial stage of highmass star and cluster formation. Therefore, a difference between properties of Galactic center IRDCs and properties of Galactic disk IRDCs would represent a difference of the process of high-mass star formation between the two regions. To resolve this issue, we (1) identify IRDCs in the Galactic center region as regions of flux decrement relative to the background at 8 um, and (2) use submm (450 and 850 um) and 1.1 mm data toward Galactic center IRDCs to determine the fluxes of the IRDCs at these wavelengths. With the fluxes, we derive a range of possible temperatures and thermal dust emissivities in these clouds and compare them to Galactic disk IRDCs. Here, we present the results of our thermal dust emission study of ~170 IRDCs in the central region of our Galaxy.

258.23

The Evolutionary State of GLIMPSE Extended Green Objects (EGOS): Results from Cm-wavelength Surveys

Claudia Cyganowski¹

¹CfA/SAO.

Exhibit Hall

A promising new diagnostic for identifying actively accreting massive young stellar objects (MYSOs) has emerged from large-scale Spitzer surveys of the Galactic plane: extended emission in the IRAC 4.5 micron band, believed to trace shocked molecular gas in active protostellar outflows. Over 300 extended 4.5 micron sources (called EGOs, Extended Green Objects, for the common coding of the [4.5] band as green in 3-color composite IRAC images), have been cataloged in the GLIMPSEI survey area. I will present results from cm-wavelength surveys of GLIMPSE EGOs designed to constrain their evolutionary state, including a Nobeyama 45-m water maser and ammonia survey, and a deep, highresolution VLA cm continuum survey.

Support for this work was provided by NSF grant AST-0808119 and by a NSF Astronomy and Astrophysics Postdoctoral Fellowship to C. Cyganowski.

258.24

Star Formation Rate Indicators in Different Scales: from Star Forming Regions to Galaxies Ka Hei Law¹, K. Gordon²

¹Johns Hopkins University, ²STScl.

Exhibit Hall

Do Star Formation Rate (SFR) indicators derived from galaxies work in star forming regions, or vice versa? We explore the behavior and effectiveness of various single- and multi-band SFR indicators across different scales. Our sample spans over 4 orders of magnitudes in total infrared luminosity and covers a wide range of spatial scale - from individual regions in nearby galaxies such as those in SMC, LMC, M33 and M31, to whole galaxies, including galaxies from the Spitzer Local Volume Legacy Survey (LVL; Dale et al. 2009), the Spitzer Infrared Nearby Galaxies Survey (SINGS; Kennicutt et al. 2003), and starburst galaxies from Engelbracht et al. 2008.

258.25

Intermediate-Mass Star-Forming Regions: Making Stars at Mass Column Densities < 1 g cm⁻² Kim Arvidsson¹, C. R. Kerton², M. J. Alexander³, H. A. Kobulnicky³, B. Uzpen⁴

¹Adler Planetarium, ²Iowa State University, ³University of Wyoming, ⁴Laramie County Community College.

Exhibit Hall

In an effort to understand the factors that govern the transition from low- to high-mass star formation, for the first time we identify a sample of intermediate-mass star-forming regions (IM SFRs) where stars up to (but not exceeding) ~8 Solar masses are being produced. We use IRAS colors and Spitzer Space

Telescope mid-IR images, in conjunction with millimeter continuum and ¹³CO maps, to compile a sample of 50 IM SFRs in the inner Galaxy. These are likely to be precursors to Herbig AeBe stars and their associated clusters of low-mass stars. IM SFRs constitute embedded clusters at an early evolutionary stage akin to compact HII regions, but they lack the massive ionizing central star(s). The photodissociation regions that demarcate IM SFRs have typical diameters of ~1 pc and luminosities of ~10⁴ Solar luminosities, making them an order of magnitude less luminous than (ultra-)compact HII regions. IM SFRs coincide with molecular clumps of mass ~10³ Solar masses which, in turn, lie within larger molecular clouds spanning the lower end of the giant molecular cloud mass range, 10^4 - 10^5 Solar masses. The IR luminosity and associated molecular mass of IM SFRs are correlated, consistent with the known luminosity-mass relationship of compact HII regions. Peak mass column densities within IM SFRs are ~0.1-0.5 g cm⁻², a factor of several lower than ultra- compact HII regions, supporting the proposition that there is a threshold for massive star formation at ~1 g cm⁻².

258.26

The University of Arizona Astronomy Club Spectroscopic Survey of CS 2-1 toward 1.1 mm Clumps in the I=29-31 HiGal Field.

Yancy L. Shirley¹, W. Schlingman¹, A. Robertson¹, K. Hardegree-Ullman¹, S. Bustamante¹, L. Hawkins¹, K. Schwarz¹, B. Smart¹, B. Terbeek¹, J. Turner¹, S. Wallace¹, J. Bally²

¹Univ. of Arizona, ²Univ. of Colorado.

Exhibit Hall

The I=29-31 line-of-sight in the plane of the Milky Way crosses two spiral arms, the edge of the molecular ring, and the end of the central Galactic bar. This direction was the initial target region of a survey of the Galactic plane at far-infrared wavelengths with the Herschel Space Observatory (HiGal). 554 1.1 mm continuum clumps have been identified by the Bolocam Galactic Plane Survey in this region. Very little is known about the nature of these sources (size, mass, luminosity, etc.) since their distances are unknown. We present spectroscopy of the BGPS continuum sources in the CS J=2-1 line observed with the Arizona Radio Observatory 12m telescope. We detect nearly 74% of the 1.1 mm sources in the CS line and characterize their physical properties by determining their kinematic distances.

258.27

Recent star formation in 30 Doradus

Guido De Marchi¹, F. Paresce², N. Panagia³, G. Beccari⁴, L. Spezzi¹, M. Sirianni¹, M. Andersen¹, WFC3 SOC ¹ESA, Netherlands, ²IASF-BO, Italy, ³STScI, ⁴ESO, Germany.

Exhibit Hall

Using observations obtained with the WFC3 camera on board the Hubble Space Telescope, we have studied the star formation properties of the central regions of 30 Dor, in the Large Magellanic Cloud. The observations clearly reveal the presence of considerable differential extinction across the field. We characterise and quantify this effect using young massive main sequence stars to derive a statistical reddening correction for each object in the field. We then search for pre-main sequence (PMS) stars by looking for objects with a strong (>5 sigma) Halpha excess emission and find about 1200 of them over the entire field. Comparison of their location in the Hertzprung--Russell diagram with theoretical PMS evolutionary tracks for the appropriate metallicity reveals that about one third of these objects have an age of < 3 Myr, compatible with that of the massive stars in the central ionising cluster R136, whereas the rest have ages up to ~30 Myr, with a median of ~10 Myr. This indicates that star formation has proceeded over an extended period of time, although we cannot discriminate between an extended episode and a series of short and frequent bursts that are not resolved in time. While the younger PMS population preferentially occupies the central regions of the cluster, older PMS objects are more uniformly distributed across the field and are remarkably few at the very centre of the cluster. We

attribute this latter effect to photoevaporation of the older circumstellar discs caused by the massive ionising members of R136.

This paper is based on Early Release Science observations made by the WFC3 Scientific Oversight Committee. We are grateful to the Director of the Space Telescope Science Institute for awarding Director's Discretionary time for this program.

258.28

Spitzer View of Massive Star Formation at Reduced Metallicity Environment

C.H. Rosie Chen¹, R. Indebetouw², Y. Chu³, R. Gruendl³, E. Muller⁴, Y. Fukui⁴, A. Kawamura⁴, G. Testor⁵, K. Gordon⁶, F. Heitsch⁷, A. Leroy⁸, M. Meixner⁶, J. Seale⁶, M. Sewilo⁶, G. Sloan⁹, B. Whitney¹⁰, SAGE Team ¹Univ. of Virginia, ²Univ. of Virginia/NRAO, ³Univ. of Illinois, ⁴Univ. of Nagoya, Japan, ⁵Observatoire de Paris, France, ⁶STScI, ⁷Univ. of North Carolina, ⁸NRAO, ⁹Univ. of Cornell, ¹⁰Space Science Institute. Exhibit Hall

Recent Spitzer mid-IR observations have revealed a large number of individually resolved massive young stellar objects (YSOs) in the Magellanic clouds, providing an excellent opportunity to study massive star formation with metallicity and galactic environment different from the Milky Way. Using Spitzer IRAC/MIPS data from SAGE survey and complementary high-resolution ground-based optical/near-IR data, we have identified YSOs in HII complexes in the Large and Small Magellanic Cloud (LMC and SMC) and a large area in the Magellanic Bridge. These systems span a metallicity range of 1/3-1/8 Zo, and different galactic environments with star formation modes from mainly self-propagating in the LMC to tidally disrupted in the Bridge. We have modeled spectral energy distributions of the YSOs and found that they have masses ranging from 4 to 45 Mo in the LMC and SMC, while the most massive ones in the Bridge are < 10 Mo. YSOs in these three systems are found to span a wide range of evolutionary stages from highly embedded to surrounded by remnant material, though for the same mass range YSOs in the Bridge appear less embedded as almost all of them are visible at optical, opposed to only a small fraction in the LMC. The smaller extinction may be due to Bridge's lower dust content in either the CO clouds or circumstellar envelopes, or both. Using surveys in H α , CO, and HI of these three systems, we further investigate the causal relationship between gas and stars. Examination of individual regions shows that massive YSOs tend to be found near ionized gas, i.e., where massive stars formed a few Myr ago, and the correlation is strongest for O-type YSOs. It appears that energy feedback plays a significant role in massive star formation. Star formation efficiencies in regions in these three systems are comparable, < 1/100-1/1000.

258.29

Probing Thermal Gas Conditions in Extragalactic Star-forming Regions Using Radio Recombination Lines

Amanda A. Kepley¹, L. Chomiuk², D. Balser³, K. Johnson¹, M. Goss³, D. Pisano⁴

¹University of Virginia, ²Harvard-Smithsonian Center for Astrophysics, ³National Radio Astronomy Observatory, ⁴West Virginia University.

Exhibit Hall

How stars form out of dense gas and dust is one of the great remaining mysteries in astronomy. While there are viable theories of Galactic star formation, theories of star formation in environments different from those in the Milky Way, which must encompass everything from dwarf galaxies to luminous and ultra-luminous infrared galaxies, are relatively unconstrained. There is a great need for quantitative information about the physical conditions of the interstellar medium in extragalactic star-forming regions and how star formation might vary with the wide range of environments (metallicity, stellar density, turbulence, magnetic fields, etc.). Studies of young, embedded star-forming regions are particularly important because they give us crucial information on the condition of the interstellar

medium in star-forming regions before the massive stars have moved off the main sequence, and thus tell us about the properties of the initial stellar population. However, because these regions are obscured by their natal dust and gas, they are poorly understood. Radio recombination lines provide an important extinction-free probe of obscured star-forming regions, yielding crucial constraints on the density, filling factor, and mass of the thermal gas in star-forming regions and number of ionizing photons present in these regions. Unfortunately, until recently these observations were tremendously difficult due to the limited bandwidth and sensitivity of previous radio interferometers. The Expanded Very Large Array (EVLA) has opened new frontiers of discovery for these powerful, but faint, diagnostic lines. We present the first observations of radio recombination lines in nearby star-forming galaxies with the recently updated Expanded Very Large Array (EVLA). These observations provide important constraints on the the physical properties of the thermal gas in these regions, and thus constraint extragalactic star formation theories.

258.30

X-rays, Blue Compact Dwarf Galaxies, and Star Formation

Mark Gorski¹, P. Kaaret¹, J. Schmitt¹

¹University of Iowa.

Exhibit Hall

Blue compact dwarf galaxies are analogs to the unevolved galaxies in the early universe, for which the correlation between star formation rate (SFR) and X-ray luminosity are largely unknown. We have selected five blue compact dwarf galaxies (BCD's) with metallicities <0.07 solar and distances less than 15 Mpc. X-ray luminosities are derived from Chandra data, while SFR data was found in the literature. An established correlation exists between the SFR and X-ray luminosity of galaxies with similar metallicities to the Milky Way. Our data suggest that, for a given X-ray luminosity, the correlation indicates an SFR that is 7 to 15 times greater than the SFR found through infrared and H α calibrations for our metal deficient BCD's. We also fit all sources with an X-ray luminosity function that fits well above a certain luminosity, but below which overestimates the number of sources.

258.31

Calibrating the Star Formation Rate and Extinction at Visible Wavelengths in Nearby Galaxies Daniel Berke¹, M. Takamiya¹

¹University of Hawai`i at Hilo.

Exhibit Hall

Star Formation Rates (SFR's) of nearby galaxies are measured in multiple wavelengths, drawing a coherent picture of star formation and allowing for corrections in visible wavelengths due to dust extinction. Galaxies at greater cosmological distances are currently measured almost solely in visible light, which may lead to a depression of the estimate of the SFR if extinction is not accurately estimated and taken into account. The purpose of this study is to provide a measure of the star formation rate and extinction in thirty near-by star-forming regions in different host galaxies, by using the H α recombination line to estimate the rate of star formation, and the Balmer decrement (the ratio of H β to H α) to estimate extinction. The SFR measured from the extinction-corrected H α luminosity in individual regions will be compared to its dust emission in the IR to study the coupling of the H α and dust emission and whether there is a trend between optical extinction and IR emission at the scales of individual star-forming regions, which may break down if the integrated IR emission in galaxies comes from regions where the H α emission is mostly absent and vice-versa.

The authors wish to acknowledge funds provided by the Cottrell Research Corporation and the National Science Foundation (AST 0909240).

258.32

Star Formation in the Outer Disks of Spiral Galaxies

Teresa Wright¹, D. Hunter¹, V. Rubin²

¹Lowell Observatory, ²Carnegie Institution.

Exhibit Hall

This is a study done in collaboration with Deidre Hunter at Lowell Observatory studying star formation in two luminous spiral galaxies NGC 801 and UGC 2885. We used ultra-deep H α images taken at the KPNO 2.1 m telescope. We compare these data to stellar images at various wavelengths and to HI maps to determine the extent of star formation activity into the outer disk in these galaxies and its relationship to the gas and older stars.

TW is grateful for an REU internship during the summer of 2010 at Northern Arizona University, funded by NSF through grant AST-1004107.

258.33

Spatial Distribution of Star Formation in High Redshift Galaxies

Ian Cunnyngham¹, M. Takamiya¹, C. Willmer², M. Chun³, M. Young⁴ ¹University of Hawaii - Hilo, ²Steward Observatory, University of Arizona, ³Institute for Astronomy, University of Hawaii, ⁴Department of Astronomy, Indiana University. Exhibit Hall

Integral field unit spectroscopy taken of galaxies with redshifts between 0.6 and 0.8 utilizing Gemini Observatory's GMOS instrument were used to investigate the spatial distribution of star-forming regions by measuring the H β and [OII] λ 3727 emission line fluxes. These galaxies were selected based on the strength of H β and [OII] λ 3727 as measured from slit LRIS/Keck spectra. The process of calibrating and reducing data into cubes -- possessing two spatial dimensions, and one for wavelength -- was automated via a custom batch script using the Gemini IRAF routines. Among these galaxies only the bluest sources clearly show [OII] in the IFU regardless of total galaxy luminosity. The brightest galaxies lack [OII] emission and it is posited that two different modes of star formation exist among this seemingly homogeneous group of z=0.7 star-forming galaxies. In order to increase the galaxy sample to include redshifts from 0.3 to 0.9, public Gemini IFU data are being sought. Python scripts were written to mine the Gemini Science Archive for candidate observations, cross-reference the target of these observations with information from the NASA Extragalactic Database, and then present the resultant database in sortable, searchable, cross-linked web-interface using Django to facilitate navigation. By increasing the sample, we expect to characterize these two different modes of star formation which could be highredshift counterparts of the U/LIRGs and dwarf starburst galaxies like NGC 1569/NGC 4449. The authors acknowledge funds provided by the National Science Foundation (AST 0909240).

P243 *Planck Poster Session* Poster Session *Exhibit Hall*

P243.01 **The Planck Mission** Planck Collaboration 2011a, **Charles R. Lawrence**¹ ¹JPL. Exhibit Hall

We present a brief summary of the main events of the first year of operations of Planck, and of the satellite performance in areas that may affect science.

The Thermal Performance of Planck

Planck Collaboration 2011b, Charles R. Lawrence¹

¹JPL.

Exhibit Hall

We describe the in-flight performance of the Planck thermal system, which includes passive radiative components and active mechanical coolers at 20 K, 4 K, and 0.1 K.

P243.03

LFI in-flight performance

Planck Collaboration 2011c, Charles R. Lawrence¹

¹JPL.

Exhibit Hall

We describe the in-flight performance of the LFI instrument after one year of operations. We discuss the main optical parameters, photometric calibration, white noise sensitivity, noise properties, and give a preliminary evaluation of the impact of the main systematic effects on the LFI data.

P243.04

HFI in-flight performance

Planck Collaboration 2011d, Charles R. Lawrence¹

¹JPL.

Exhibit Hall

We describe the in-flight performance of the HFI instrument after one year of operations. The behavior of critical parts, especially the optical system and the detection chains will be described. Overall performance will be compared to pre-launch expectations.

P243.05

LFI data processing

Planck Collaboration 2011e, Charles R. Lawrence¹

¹JPL.

Exhibit Hall

We describe the LFI processing pipeline that was used to obtain LFI temperature maps from the first 10 months of survey data and assess their accuracy. This is the input information for producing Planck Early Release Compact Source Catalogue as well as the early scientific analyses using LFI data.

P243.06

HFI data processing

Planck Collaboration 2011f, Charles R. Lawrence¹

¹JPL.

Exhibit Hall

We describe the HFI processing pipeline that was used to obtain HFI temperature maps from the first 10 months of survey data and assess their accuracy. This is the input information for producing Planck Early Release Compact Source Catalogue as well as the early scientific analyses using HFI data.

The Planck Early Release Compact Source Catalog

Planck Collaboration 2011g, Charles R. Lawrence¹

¹JPL.

Exhibit Hall

Planck observes the entire sky at frequencies between 30 GHz and 857 GHz at spatial resolutions of 33' to 5', respectively. We present the contents of the Planck Early Release Compact Source Catalogue, constructed from the first all sky coverage, and discuss the features of the data products being released to the astronomical community.

P243.08

Planck Early SZ Results I

Planck Collaboration 2011h, Charles R. Lawrence¹

¹JPL.

Exhibit Hall

We present the first results from analyses of the Sunyaev-Zel'dovich effect and clusters of galaxies in the Planck all sky survey.

P243.09

Planck Early SZ Results II

Planck Collaboration 2011i, Charles R. Lawrence¹

¹JPL.

Exhibit Hall

We present the first results from analyses of the Sunyaev-Zel'dovich effect and clusters of galaxies in the Planck all sky survey.

P243.10

Planck Early SZ Results III

Planck Collaboration 2011j, **Charles R. Lawrence**¹

- ¹JPL.
- Exhibit Hall

We present the first results from analyses of the Sunyaev-Zel'dovich effect and clusters of galaxies in the Planck all sky survey.

P243.11

Planck Early SZ Results IV

Planck Collaboration 2011k, Charles R. Lawrence¹

¹JPL.

Exhibit Hall

We present the first results from analyses of the Sunyaev-Zel'dovich effect and clusters of galaxies in the Planck all sky survey.

P243.12

Planck Early SZ Results V

Planck Collaboration 2011l, Charles R. Lawrence¹

¹JPL.

Exhibit Hall

We present the first results from analyses of the Sunyaev-Zel'dovich effect and clusters of galaxies in the Planck all sky survey.

Statistical Properties of Extragalactic Radio Sources in the 1-st year Planck Low Frequency Surveys Planck Collaboration 2011m, **Charles R. Lawrence**¹

¹JPL.

Exhibit Hall

We exploit the information content of the Planck Early Release Compact Source Catalogue (ERCSC) to analyze the main statistical properties of extragalactic radio sources and compare them with previously published results.

P243.14

Planck Early Survey of Extreme Radio Sources

Planck Collaboration 2011n, Charles R. Lawrence¹

¹JPL.

Exhibit Hall

The Planck Early Release Compact Source Catalog contains hundreds of extragalactic radio sources, many with spectral energy distributions extending to 143 GHz. The Planck observations are complemented by approximately simultaneous ground-based observations at frequencies below and overlapping the Planck frequency bands. We describe the spectral energy distributions and other properties of some extreme radio sources.

P243.15

Spectral Energy Distributions and Radio Continuum Spectra of Northern Extragalactic Radio Sources Planck Collaboration 2011o, **Charles R. Lawrence**¹

¹JPL.

Exhibit Hall

We present spectral energy distributions of a Northern sample of extragalactic radio sources, based on the Planck ERCSC and simultaneous multifrequency data. The large frequency coverage of Planck allows a look at the more detailed radio continuum spectra. SED modelling methods are briefly discussed, with an emphasis on proper modelling of the synchrotron component.

P243.16

Planck, Swift and Fermi Simultaneous SEDs of a Large Sample of X and Gamma-ray Selected Blazars Planck Collaboration 2011p, **Charles R. Lawrence**¹

¹JPL.

Exhibit Hall

We present simultaneous observations of a sample of X- and Gamma-ray selected blazars by Planck, Swift, and Fermi. For each object we show a simultaneous spectral energy distribution from radio to gamma-ray frequencies. We determine some parameters that describe the shape of the SED (both the synchrotron and inverse Compton component) and comment on physical models.

P243.17

The Planck View of Local Galaxies

Planck Collaboration 2011q, **Charles R. Lawrence**¹

¹JPL.

Exhibit Hall

We use the Planck Early Release Compact Source Catalogue to study the dust properties of galaxies in the local universe (z<0.25.)

Nature of the Millimeter Excess Emission in the Magellanic Clouds

Planck Collaboration 2011r, Charles R. Lawrence¹

¹JPL.

Exhibit Hall

Using Planck maps combined with IRAS data, we construct dust apparent temperature and optical depth in the Small and Large Magellanic Clouds. The spatial distribution of the dust optical depth is used to constrain the nature of the millimeter excess in these low metallicity galaxies.

P243.19

Early Planck Results on the Far-infrared/Submillimeter Properties of Local Luminous Galaxies Planck Collaboration 2011s, **Charles R. Lawrence**¹

¹JPL.

Exhibit Hall

We present the 350 micron to 1.4mm spectral energy distribution of local luminous galaxies. We discuss the SED in the context of the IRAS measurements and present implications for the energetics of the sources.

P243.20

Power Spectrum of Cosmic Infrared Background Anisotropies

Planck Collaboration 2011t, Charles R. Lawrence¹

¹JPL.

Exhibit Hall

Studies of both correlations in the spatial distribution of infrared galaxies as a function of redshift and individual high redshift infrared-luminous galaxies are essential to understanding galaxy formation and evolution. Due to confusion at far-infrared and sub-millimeter wavelengths, these correlations must be searched for in the anisotropies of the Cosmic Infrared Background. We present Planck measurements of the CIBA power spectrum, and interpret the results in terms of large-scale bias and clustering of star-forming galaxies.

P243.21

Distribution of the Thermal Dust Temperature and Optical Depth in the Solar Neighborhood, Searching for the Dark Molecular Gas Component

Planck Collaboration 2011u, Charles R. Lawrence¹

¹JPL.

Exhibit Hall

Using Planck maps combined with IRAS data, we construct all-sky maps of the dust apparent temperature and optical depth. The optical depth maps are used to look for excess emission with respect to neutral and molecular gas tracers in order to investigate the presence of dark molecular gas and to quantify its importance in the solar neighborhood.

P243.22

New Light on Microwave Emission from Spinning Dust Grains

Planck Collaboration 2011v, Charles R. Lawrence¹

¹JPL.

Exhibit Hall

Using Planck maps combined with ancillary multi-frequency data, we construct spectral energy distributions for previously known regions of anomalous excess microwave emission. We model the

spectra with a combination of components, and identify new regions of anomalous excess emission for further study.

P243.23

Dust Properties Throughout the Milky Way

Planck Collaboration 2011w, Charles R. Lawrence¹

¹JPL.

Exhibit Hall

Planck observes the entire sky from 30 to 857 GHz. The observed foreground emission contains contributions from different phases of the interstellar medium that vary as a function of Galactic radius. We show how the Planck galactic emission separates into different gaseous components (atomic, molecular, and ionised) as well as into a number of Galactocentric rings. This technique provides the necessary information to study dust properties (emissivity, temperature, dust to gas ratio...) throughout the Milky Way.

P243.24

The mm/submm Properties of a Sample of Galactic Cold Cores

Planck Collaboration 2011x, Charles R. Lawrence¹

¹JPL.

Exhibit Hall

We present the physical properties and discuss the nature of a selection of interesting cold cores drawn from the Cold Core Catalogue of Planck Objects (C3PO). A first analysis of the spectral energy distributions, temperature, density, size, mass, and dust emissivity is performed for 10 individual sources.

P243.25

The Galactic Cold Core Population Revealed by the First All Sky Survey

Planck Collaboration 2011y, Charles R. Lawrence¹

¹JPL.

Exhibit Hall

We present the statistical properties of the [[Unsupported Character - fi]]rst version of the Cold Core Catalogue of Planck Objects (C3PO) in terms of spatial distribution, temperature, distance, mass, and morphology.

P243.26

Early Planck Results: Dust in the Diffuse Interstellar Medium at High Galactic Latitudes Planck Collaboration 2011z, **Charles R. Lawrence**¹

¹JPL.

Exhibit Hall

We present a joint analysis of Planck, IRAS, and 21 cm Green Bank data of selected high Galactic latitude fields, and discuss the properties of dust in the diffuse interstellar medium close to the Sun and in the Galactic halo.

P243.27 Dust in Molecular Clouds

Planck Collaboration 2011aa, Charles R. Lawrence¹

¹JPL.

Exhibit Hall

We present Planck maps of a selection of nearby molecular clouds. The combination with IRAS data allows us to derive the full emission spectrum of the dust in thermal equilibrium with the incident radiation. We discuss the evolution of the emitting properties of the dust particles, from the outer diffuse parts of the molecular clouds to the dense star forming regions.

P243.28

Planck Visualization Project: Seeing and Hearing the CMB

Jatila Van Der Veen¹, P. M. Lubin, 2¹, B. Alper, 3¹, W. Smith, 4¹, R. McGee, 5¹, US Planck Collaboration ¹University of California Santa Barbara.

Exhibit Hall

The Planck Education and Public Outreach collaborators at the University of California, Santa Barbara and Purdue University have prepared a variety of materials to present the science goals of the Planck Mission to the public. Here we present our interactive simulation of the Cosmic Microwave Background, in which the user can change the ingredients of the universe and hear the different harmonics. We also present how we derive information about the early universe from the power spectrum of the CMB by using the physics of music for the public.

Tuesday, January 11, 2011, 10:00 AM - 11:30 AM 201

Kepler II Oral Session *Ballroom 6B*

201.01

A First of its Kind Hierarchical Triple Found by Kepler

Joshua A. Carter¹, D. Fabrycky², M. J. Holman³, D. Ragozzine³, Kepler Science Team ¹Smithsonian Astrophysical Observatory, ²Harvard-Smithsonian Center for Astrophysics, ³Institute for Theory and Computation, Smithsonian Astrophysical Observatory.

10:00 AM - 10:10 AM

Ballroom 6B

In addition to the discovery and characterization of hundreds of planetary candidates, NASA's Kepler mission has opened a new regime in time-domain photometry. Kepler's high-precision, high-cadence, long-term photometric monitoring has the potential to unveil a number of previously unseen and likely unforeseen astrophysical events. We report on the discovery of one such event which is associated with a hierarchical stellar triple. We describe the results of an analysis of Kepler data that determined the bulk parameters for this system and comment on the implications from this analysis related to stellar structure, dynamics, and evolution. Kepler was selected as the 10th mission of the Discovery Program. Funding for this mission is provided by NASA, Science Mission Directorate.

201.02

KOI-125 And KOI-130: Two Large Transiting Low Mass Companions Discovered By The Kepler Mission Pavel Machalek¹, J. Rowe¹, J. Christiansen¹, J. Jenkins¹, D. Caldwell¹, L. C. A. Buchhave², G. Torres³, S. Quinn³, P. MacQueen⁴, W. Cochran⁵, M. Endl⁴, Kepler Science Team ¹SETI / NASA Ames, ²Niels Bohr Institute, Denmark, ³Harvard-Smithsonian Center for Astrophysics, ⁴McDonald Observatory, ⁵The University of Texas at Austin.

10:10 AM - 10:20 AM

Ballroom 6B

Brown dwarfs span the boundary between hydrogen burning stars and planets. We present photometric and radial velocity analysis of two large transiting low mass companions KOI-125 and KOI-130 discovered by the Kepler mission. Precise determination of masses and radii will help fill in the mass-radius relation for sub-stellar and M-dwarf companions. KOI-125 is likely a brown-dwarf companion and KOI-130 is likely a M-dwarf companion on an eccentric orbit.

Kepler was selected as the 10th mission of the Discovery Program. Funding for this mission is provided by NASA, Science Mission Directorate.

201.03

Follow-up Observations and Analysis of Low-mass Eclipsing Binaries in the Kepler Field Jerome A. Orosz¹, W. F. Welsh¹, R. A. Wade², T. Fetherolf³, T. A. Gregg¹, C. M. Heffner¹, A. Belur¹ ¹San Diego State Univ., ²The Pennsylvania State University, ³Palomar College. 10:20 AM - 10:30 AM

Ballroom 6B

There is a long-standing discrepancy between theoretical and observational mass-radius relations at the bottom of the main-sequence, namely that the observed radii of low-mass stars are up to 15% larger than predicted. This discrepancy may be related to strong stellar magnetic fields, not properly accounted for in current theoretical models. All previously well-characterized low-mass main-sequence EBs have periods of a few days or less, and their components are therefore expected to be rotating rapidly as a result of tidal synchronization, thus generating strong magnetic fields. We hypothesize that the stars in the binaries with longer orbital periods will better match the assumptions of theoretical stellar models. The Kepler mission has observed close to a thousand detached and semi-detached binaries nearly continuously since May, 2009. We have identified a sample of 10 of these binaries that have either one or two components with masses below 1 solar mass. This sample contains a mixture of shorter period systems that show clear evidence for strong spot activity and longer period systems with no evidence for spot activity. Extensive ground-based follow-up observations will be needed to fully exploit this unique sample. We have begun a program to obtain multi-color photometric observations from Mount Laguna Observatory and spectroscopic observations with the Hobby-Eberly Telescope. We will give a progress report on the observations to date.

Funding for the Kepler mission is provided by NASA's Science Mission Directorate. JAO acknowledges support from the NSF grant AST-0808145. WFW and JAO acknowledge support from the Kepler GO office. TF acknowledges support from the NSF REU program at San Diego State University that is supported by grant AST-0850564.

201.04

Identification and Follow-Up Observations of Low-Mass Eclipsing Binaries from Kepler

Jeffrey Coughlin¹, M. Lopez-Morales², R. I. Marzoa³, T. Harrison¹, N. Ule¹, D. Hoffman⁴ ¹New Mexico State Univ., ²Institut de Ciencies de l'Espai (CSIC-IEEC), Spain, ³Instituto de Astrofisica de Canarias, Spain, ⁴California Institute of Technology.

10:30 AM - 10:40 AM

Ballroom 6B

An outstanding problem in Astronomy for the past 15^+ years has been that the radii of low-mass, (M < 1.0 M_{\odot}), main-sequence stars in eclipsing binary systems are consistently about ~15% larger than predicted by theoretical models. The main cause is hypothesized to be rapid rotation due to binary spin-

up, as all but one of the currently known systems have P < 3.0 days. We present 100^+ new low-mass, main-sequence, double-lined eclipsing binaries (LMMS DDEBs) from both our Kepler Guest Observer Program, as well as the initial Kepler public data release. We identify over 25 new systems with P > 10 days, extending the sample of LMMS DDEBs into this completely heretofore unexplored period range. We present the initial results of our intensive observing campaign to obtain ground-based radial-velocity and multi-color photometry follow-up of these long-period systems, in order to determine precise masses and radii. We thank all the hard-working members of the Kepler team, and acknowledge support from the Kepler Guest Observer Program, the New Mexico Space Grant Consortium, and a NSF Graduate Research Fellowship.

201.05

Stellar Rotation and Activity with Kepler

Lucianne M. Walkowicz¹, G. Basri¹ ¹UC Berkeley. 10:40 AM - 10:50 AM

Ballroom 6B

Stellar magnetic activity leads to a plethora of observable effects, from star spots that modulate the stellar brightness on the order of weeks, to flares, which release highly energetic radiation over the course of a few hours. Although Kepler's main goal is the discovery of exoplanets, its unmatched precision photometry provides a wealth of information regarding stellar astrophysics. Because of the intimate link between stellar rotation and the generation of the magnetic field, periodic brightness variations due to starspots may be used to gain insight into the magnetic dynamo. In addition, an understanding of the stellar radiation environment provides context for studies of potential attendant planets. I will discuss our ongoing work with Kepler to characterize stellar variability due to spots and flares, and to determine rotation periods for the these stars. Kepler was selected as the 10th mission of the Discovery Program. Funding for this mission is provided by NASA, Science Mission Directorate.

201.06

Kepler Full-Frame Image Variable Star Catalog

Karen Kinemuchi¹, M. Still¹, M. Fanelli¹, Kepler Science Team

¹NASA-Ames Research Center.

10:50 AM - 11:00 AM

Ballroom 6B

Kepler, NASA's discovery mission to find Earth-sized planets within the habitable zone of nearby stars, provides an unique and powerful resource to perform serendipitous time-domain astrophysics. There are 10⁷ sources brighter than the 21st magnitude Kepler confusion limit within the Kepler field. Thirty minute cadence relative photometry is good to 2% accuracy at 19th magnitude. However, telemetry bandwidth limits the data collection to only ~170,000 targets per quarter, of which 96% are reserved for the primary, brighter than 16th magnitude, red-dominated exoplanet program. Through Guest Observer and open consortium avenues, the onus is upon the astrophysics community to choose their 4% share of the targets carefully so that serendipitous science opportunities with Kepler are optimized. One method for identifying potential targets of high astrophysical interest is to locate the variable objects in the Kepler field using the publicly available, 30-min exposure, Full-Frame Images (FFIs). These images are stored and transmitted by the spacecraft at one-month intervals, principally for engineering purposes. Here we describe a pilot study using eight FFIs obtained in rapid sequence over 1.5 days during the spacecraft commissioning phase. We present a catalog and light curves of variable objects mined from these "Golden" FFIs. Many of these objects will be eclipsing binaries, pulsators, eruptive stars, and other exotic variable stars exhibiting large brightness changes. This variable star catalog will provide an

excellent stepping stone for Kepler astrophysics projects through the Kepler Asteroseismic Science Consortium (KASC), the Guest Observer Program, or Guest Observer Director's Discretionary Time. Kepler was selected as the 10th mission of the Discovery Program. Funding for this mission is provided by NASA, Science Mission Directorate.

201.07

Search for Variables in the Kepler Field on DASCH Plates

Sumin Tang¹, J. Grindlay¹, E. Los¹, M. Servillat¹

¹Harvard-Smithsonian Center for Astrophysics.

11:00 AM - 11:10 AM

Ballroom 6B

The Digital Access to a Sky Century @ Harvard (DASCH) is a project to digitize the half a million glass photographic plates over the period 1880s-1980s. This 100 year coverage is a unique resource for studying temporal variations in the universe. Here we present our variable search algorithms and variable catalog in the Kepler fields based on ~3000 scanned plates.

We use the KIC spectral classifications to search for long-term variability of any main sequence stars, particularly M dwarfs. We apply a variability search technique developed for DASCH and set limits on the fraction of main sequence stars, by spectral type, which show detectable (>0.2mag) variability on timescales ~10-100y. Such limits are of particular interest for M dwarfs given the recent discoveries of their planet systems.

201.08

The Asteroseismic Age and Radius of the Solar-type Subgiant KIC 11026764 from Kepler Photometry Travis S. Metcalfe¹, Kepler Asteroseismic Science Consortium

¹NCAR.

11:10 AM - 11:20 AM

Ballroom 6B

The primary science goal of the Kepler mission is to provide a census of exoplanets in the solar neighborhood, including the identification and characterization of habitable Earth-like planets. The asteroseismic capabilities of the mission are being used to determine precise radii and ages for the target stars from their solar-like oscillations. Chaplin et al.(2010) published observations of three bright G-type stars, which were monitored during the first 33.5 days of science operations. One of these stars, the subgiant KIC 11026764, exhibits a characteristic pattern of oscillation frequencies suggesting that it has evolved significantly. We have derived asteroseismic estimates of the properties of KIC 11026764 from Kepler photometry combined with ground-based spectroscopic data. We present the results of detailed modeling for this star, employing a variety of independent codes and analyses that attempt to match the asteroseismic and spectroscopic constraints simultaneously. We determine both the radius and the age of KIC 11026764 with a precision near 1 percent, and an accuracy near 2 percent for the radius and 15 percent for the age. Continued observations of this star promise to reveal additional oscillation frequencies that will further improve the determination of its fundamental properties.

201.09

The Kepler Light Curve of V344 Lyrae: Constraining the Thermal-Viscous Accretion Disk Instability John K. Cannizzo¹, M. D. Still², S. B. Howell³, M. A. Wood⁴, A. P. Smale⁵ ¹NASA/GSFC/CRESST/UMBC, ²Bay Area Environmental Research Inst., Inc., ³National Optical Astronomy Observatory, ⁴Florida Institute of Technology, ⁵NASA.

11:20 AM - 11:30 AM

Ballroom 6B

We present time dependent modeling based on the accretion disk limit cycle model for a 270 d light curve of the short period SU UMa-type dwarf nova V344 Lyr taken by Kepler. The unprecedented precision and cadence (1 minute) far surpass that generally available for long term light curves. The data encompass two superoutbursts and 17 normal (i.e., short) outbursts. The main decay of the superoutbursts is nearly perfectly exponential, decaying at a rate ~12 d/mag, while the much more rapid decays of the normal outbursts exhibit a faster-than-exponential shape. Our modeling using the basic accretion disk limit cycle can produce the main features of the V344 Lyr light curve, including the peak outburst brightness. Nevertheless there are obvious deficiencies in our model light curves: (1) The rise times we calculate, both for the normal and superoutbursts, are too fast. (2) The superoutbursts are too short. (3) The shoulders on the rise to superoutburst have more structure than the shoulder in the observed superoutburst and are too slow, comprising about a third to half of the total viscous plateau, rather than the ~10% observed. However, one of the alpha_{cold} -> alpha_{hot} interpolation schemes we investigate (one that is physically motivated) does yield longer superoutbursts with suitably short, less structured shoulders.

202

Exploring the Far-IR/Sub-mm with the Herschel Space Observatory Oral Session *Ballroom 6C*

202.01

Far-ir Spectroscopy Of Various Mineral Groups: Providing Laboratory Data For Herschel

Tatyana Brusentsova¹, R. Peale¹, D. Maukonen¹, P. Figueiredo¹, G. Harlow², D. Ebel², C. Lisse³ ¹University of Central Florida, ²American Museum of Natural History, ³Johns Hopkins University Applied Physics Laboratory.

10:00 AM - 10:10 AM Ballroom 6C

To aid in interpreting data from Herschel Space Observatory Photodetector Array Camera and Spectrometer (PACS), we have collected mass absorption coefficient spectra in the wavelength range 15 to 250 micron of micron-sized powders for more than 140 mineral species representing various mineral groups. Mineral groups investigated included nesosilicates (olivines, garnets, phenakite), inosilicates (pyroxenes, pyroxenoids, amphiboles), sorosilicates, cyclosilicates, tectosilicates (silicas, feldspars), phyllosilicates, carbonates, sulfides, and oxides. The mineral samples were selected from AMNH mineral collection, chemical and crystallographic identity of all minerals was confirmed by means of electron microprobe and grain and powder XRD. Samples were ground to micron dimensions and the micron size distribution was ensured by Stokes settling, verified by scanning electron microscopy. Milligram quantities of mineral sample were dispersed in polyethylene powder and melted into pellets. Spectra were collected using a Fourier spectrometer with globar source, mylar beamsplitter, and a 4 K bolometer. Temperature dependence of the spectra down to 15 K revealed sharpening and blue-shifts of the characteristic absorption lines, and in some cases, resolution of additional features not seen at room temperature. Mineral spectra in the far-IR region are highly characteristic of mineral group, crystal structure and chemical composition. The spectral data obtained in this study, together with the accompanying mineral characterization data, will be added to Planetary Data System database to be used for mineral identification in cosmic dust populations, based on far-IR emission spectra of collected by Herschel and similar space IR missions.

202.02

Clustering Properties of Far-infrared Sources in the Herschel infrared GALactic Survey (Hi-Gal) Science Demonstration Phase Fields.

Nicolas Billot¹, E. Schisano², S. Molinari³, M. Pestalozzi³, Hi-GAL team

¹Infrared Processing and Analysis Center, NASA Herschel Science Center, Caltech, ²INAF - IFSI, Italy, ³INAF - IFSI, Italy.

10:10 AM - 10:20 AM

Ballroom 6C

While the study of star forming activity usually relies on fitting spectral energy distributions to probe the physical properties of forming stars, we explore an alternative method to complement this multi-wavelength strategy: we use a Minimum Spanning Tree (MST) algorithm to characterize the spatial distribution of Galactic Far-IR sources and derive their clustering properties. We aim at revealing the spatial imprint of different types of star forming processes, e.g. isolated spontaneous fragmentation of dense molecular clouds, or events of triggered star formation around Hii regions, and evidence global properties of star formation in the Galaxy.

We plan on exploiting the entire HiGAL survey of the inner Galactic plane (270 square degrees observed in 5 bands between 70 and 500 microns, P.I. Sergio Molinari) to gather significant statistics on the clustering properties of star forming regions, and to look for possible correlations with source properties such as mass, temperature or evolutionary stage. In this poster we present a pilot study of our project on two 2×2 square degrees fields centered at longitudes I=30 and 59 degrees obtained during the Science Demonstration Phase (SDP) of the Herschel mission.

202.03

Herschel Observations Of Isolated Star-forming Clouds: Dust-temperature Maps, Dust Properties And Molecular Freezeout

Amelia Marie Stutz¹, R. Launhardt¹, O. Krause¹, Z. Balog¹, T. Henning¹, H. Linz¹, H. Lippok¹, M. Nielbock¹, M. Schmalzl¹, EPoS

¹*MPIA, Germany.* 10:20 AM - 10:30 AM *Ballroom 6C*

Herschel scan map observations, when combined with ground-based submm continuum and NIR extinction data, have the power to observationally constrain the dust properties in molecular clouds at a level where only model assumptions or lab measurements were available in the past. As part of the EPoS (Early Phases of Star Formation) Key Programme, we have selected a sample of sources that is ideal for taking full advantage of the unique capabilities: our sources are well-characterized nearby, isolated small molecular clouds, selected to be in regions with exceptionally low cirrus confusion noise. The excellent spectral sampling of the Herschel measurements enable a detailed comparison of dust properties, such as submm/FIR emissivity vs. NIR extinction. We show what is needed to derive spatially resolved reliable dust temperature maps, and how these very accurate temperature constraints affect the resulting (column) density profiles. Using the example of Barnard 335, a prototypical Class 0 protostar in an isolated Bok globule, we show how external heating by the interstellar radiation field, cooling by dust at high column densities, and internal heating by the embedded protostar affect the temperature structure of the cloud. A comparison between our dust-temperature and column density maps and previous molecular observations reveals important molecular freezeout thresholds and the physical properties at the interface between the cloud envelope and the molecular outflow.

202.04 Early Results From The Herschel Key Program: Dust, Ice, And Gas In Time (DIGIT) Neal J. Evans¹, DIGIT Team

¹Univ. of Texas at Austin.

10:30 AM - 10:40 AM

Ballroom 6C

I will present results that are in hand by the time of the meeting from the DIGIT Key Program. The program includes full PACS spectroscopy of both embedded objects and disks around stars, as well as some HIFI observations and PACS photometry of selected wTTs. Results so far show that embedded sources very commonly have emission from highly excited states of CO, OH, and water, as well as fine structure lines from OI. The analysis of the CO data via rotation diagrams indicates that there are both warm (T around 300 K) and hot (T above 1000 K) components. The OH and water lines primarily arise in somewhat lower temperature regions. The limited data on disks reveals a nearly pure forsterite feature and highly excited CO lines in the disk around HD100546. This work is supported by JPL Contract No. 1358118.

202.05

Herschel Photometry of the Tucana-Horologium Association

Jessica Donaldson¹, A. Roberge², W. Dent³

¹Dept. of Astronomy, University of Maryland, College Park, ²Exoplanets and Stellar Astrophysics Lab., NASA Goddard Space Flight Center, ³ALMA JAO, Chile.

10:40 AM - 10:50 AM

Ballroom 6C

The GASPS Open Time Key Programme for the Herschel Space Observatory represents a new opportunity to survey protoplanetary disks and young debris disks at far-IR wavelengths. We present preliminary PACS 70 and 160 micron photometry of eighteen stars in the 30 Myr-old Tucana-Horologium association. Of these eighteen, six were detected in the 70 micron band. Two were also detected in the 160 micron band. We constructed SEDs for these systems using optical data from Hipparcos (B and V), near-IR data from 2MASS (J, H, and K), mid-IR data from IRAS and Spitzer MIPS (12 and 24 microns, respectively), and the new far-IR data from PACS. For the stars showing IR excess emission, we fit the data using models of optically thin debris disks with realistic dust grain properties. Our SED fitting constrains six disk parameters: the disk mass, grain size distribution, minimum and maximum grain sizes, and the minimum and maximum radial distance of the disk. The best-fit parameters give us a sense of the dust abundance and spatial distribution in these systems.

202.06

Results from the Herschel Oxygen Project

Paul Goldsmith¹, Herschel Oxygen Project (HOP) Team ¹JPL.

10:50 AM - 11:00 AM

Ballroom 6C

Oxygen is the third most abundant element in the cosmos. In the gas phase, oxygen can be ionized, atomic, or in molecular, and it is also incorporated into grains. Gas-phase chemistry models predict molecular oxygen (O2) to be almost as abundant as carbon monoxide (CO). A number of searches for molecular oxygen have been carried out, including ground-based searches for the isotopologue ¹⁶O¹⁸O and searches for O₂ in redshifted galaxies. Searches for Galactic O2 carried out with the SWAS and Odin spacecraft have yielded upper limits on the abundance of molecular oxygen typically 1 to 2 orders of magnitude below those predicted by gas-phase models. There has been a fairly clear detection of O₂ in

one source, again indicating a low abundance. A variety of explanations have been proposed to explain this low abundance. Some of these are based on depletion of atomic oxygen onto dust grains, resulting in incorporation of this species into water that remains on the grain surface. Available gas-phase oxygen is largely incorporated into CO, leaving little for gas-phase O₂. Other models involve circulation of material between UV-irradiated and well-shielded regions.

The Herschel Open Time Key Project HOP (Herschel Oxygen Project) addresses this important problem in astrochemistry, exploiting the high angular resolution and sensitivity of the Herschel HIFI instrument to observe 3 rotational transitions of O_2 in a broad sample of molecular clouds. The sensitivity and angular resolution of HIFI is a dramatic improvement over anything previously available at these frequencies. These data should, whether yielding detections or significantly improved upper limits, provide critical information about interstellar chemistry and the structure of these varied molecular regions. We will discuss the HOP observations to date including exceptionally low upper limits to the abundance of O_2 as well as some provocative, tentative positive results.

202.07

The Dust-to-Gas Ratio in NGC 6946 and M 101: New Results from Herschel

Karin M. Sandstrom¹, A. K. Leroy², F. Walter¹, G. Aniano³, B. T. Draine³, D. Calzetti⁴, R. C. Kennicutt⁵, KINGFISH Team

¹Max Planck Institute for Astronomy, Germany, ²National Radio Astronomy Observatory, ³Department of Astrophysical Sciences, Princeton University, ⁴Department of Astronomy, University of Massachusetts, Amherst, ⁵Institute of Astronomy, University of Cambridge, United Kingdom.

11:00 AM - 11:10 AM

Ballroom 6C

The dust-to-gas ratio (DGR) controls many aspects of the state of the interstellar medium. Measuring the DGR requires a full accounting of dust, including cold dust that emits most strongly at far-IR and submm wavelengths, and a full accounting of gas, including any molecular gas. Unfortunately, poorlyconstrained cold dust masses, lack of molecular gas observations and a possibly varying conversion between CO line intensities and molecular gas masses (i.e. Xco) have made DGR measurements difficult, particularly resolved within galaxies. The availability of Herschel observations from the KINGFISH survey lets us take a major step forward in studying the variations in the dust-to-gas ratio and their drivers. We present a resolved study of the DGR in two nearby, face-on spiral galaxies observed with KINGFISH: NGC 6946 and M 101. We make use of new CO measurements from the HERACLES survey, a new generation survey of molecular gas in nearby galaxies at the IRAM 30m telescope. The combination of these datasets lets us study DGR and Xco as a function of radius and metallicity in these two galaxies. We also present new results on dust in the tidal feature of NGC 3077, a galaxy in the M 81 group observed as part of KINGFISH. Using these new observations from KINGFISH and HERACLES, we study the variations of DGR over a wide range of extragalactic environments.

Based on observations obtained with the Herschel Space Telescope as part of KINGFISH (Key Insights on Nearby Galaxies: a Far Infrared Survey with Herschel; P.I.: R.C. Kennicutt), one of the Herschel Open Time Key Projects.

202.08

Herschel PACS Observations Of Massive Molecular Outflows In ULIRGs And What May Drive Them Jacqueline Fischer¹, E. González-Alfonso², E. Sturm³, J. Graciá-Carpio³, S. Hailey-Dunsheath³, S. Veilleux⁴, A. Poglitsch³, A. Contursi³, D. Lutz³, R. Genzel³, A. Sternberg⁵, A. Verma⁶, L. Tacconi³ ¹NRL, ²Universidad de Alcala de Henares, Spain, ³Max-Planck-Institut für extraterrestrische Physik, Germany, ⁴University of Maryland, ⁵Tel Aviv University, Israel, ⁶Oxford University, United Kingdom. 11:10 AM - 11:20 AM

Ballroom 6C

The first Herschel observations of OH absorption in ULIRGs are revealing P-Cygni profiles indicative of massive molecular outflows suggestive of AGN feedback. We present the early observations of these outflows and the estimated ranges of gas mass, dynamical timescale, mechanical power, mass loss rate, and kinematic energy as well as arguments that radiation pressure may drive them. Our estimates of the outflow parameters will improve when observations of excited rotational levels are obtained. Herschel is an ESA space observatory with science instruments provided by Principal Investigator consortia. Basic research in IR astronomy at NRL is funded by the US ONR. J.F. acknowledges support from the NHSC.

202.09

GBT Zpectrometer CO(1-0) Observations of the Herschel-ATLAS Strongly Lensed Sub-mm Galaxies

David T. Frayer¹, A. Harris², A. Baker³, R. Ivison⁴, I. Smail⁵, M. Negrello⁶, R. Maddalena¹, Herschel ATLAS Team

¹NRAO, ²University of Maryland, ³Rutgers, ⁴ROE, United Kingdom, ⁵Durham, United Kingdom, ⁶Open University, United Kingdom.

11:20 AM - 11:30 AM

Ballroom 6C

The Herschel Astrophysical Terahertz Large Area Survey (H-ATLAS) has uncovered a population of strongly-lensed submillimeter galaxies (SMGs). We report on our ongoing Zpectrometer observations on the Green Bank Telescope (GBT) to measure the redshifts and constrain the masses of the cold molecular gas reservoirs for this sample of SMGs at z~2--3.5. We find typical L(IR)/L'(CO) ratios of 100--150 Lsun (K km/s pc²)⁻¹, which are consistent with those found for local ULIRGs and other high-redshift SMGs. We find no evidence for enhanced L(IR)/L'(CO(1-0)) ratios for the SMG population in comparison to local ULIRGs, in contrast to previous claims based on the higher-J CO transitions. The GBT/Zpectrometer results highlight the power of using the CO lines to derive blind redshifts, which is challenging for the SMG population at optical wavelengths given their high obscuration. The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

203

Radio Sky Surveys Project with the Allen Telescope Array Special Session *Ballroom 6A*

203.01 **The Radio Sky Surveys Project Geoffrey C. Bower**¹ ¹*UC, Berkeley.* 10:00 AM - 10:10 AM

Ballroom 6A

This is a revolutionary period for astronomy. New detector and computing technologies are enabling telescopes and surveys that have not been previously possible, transforming astronomy from a data-starved to a data-rich science. Systematic and synoptic surveys at all wavelengths are providing new insights into all aspects of astronomy. At radio wavelengths, surveys have been integral to progress in many fields and led to ground-breaking results such as the discovery of pulsars.

We describe here the Radio Sky Surveys Project (RSSP): a set of surveys conducted with an expanded Allen Telescope Array (ATA). The RSSP exploits unique capabilities of the ATA, especially the world-leading survey speed of a 256-element array and the ability to conduct multiple science programs

commensally. Key science areas are in the dynamic radio sky, SETI, star formation, galactic structure, galaxy evolution, cosmology and fundamental physics through pulsar observations. The planned surveys will be an important complement to the significant capabilities of the existing radio facilities and will provide results complementary to the next generation of instruments across the spectrum. The technological advances necessary for the RSSP will lay the foundation for the Square Kilometer Array (SKA). Research into large-N correlators, data management, survey management, array construction and operations, and automated calibration, flagging, and image processing are central to the success of the RSSP and will be applicable to the SKA.

We describe here the technical capabilities of an expanded ATA, an overview of the science goals, and present a sampling of current scientific results from the ATA.

203.02

Studying Transient Events By Radio and Visible Light Observations. Eran Ofek¹ ¹Caltech. 10:10 AM - 10:20 AM Ballroom 6A I will discuss several topics related to transients that may release energy in visible light and radio

I will discuss several topics related to transients that may release energy in visible light and radio wavebands. Among these are GRBs and SNe. In addition I will describe some recent results from our VLA search for Bower et al.-like transients.

203.03

The Unique Capabilities of the Allen Telescope Array for Pulsar Timing and Gravitational Wave Detection

Maura McLaughlin¹

¹West Virginia University.

10:20 AM - 10:30 AM

Ballroom 6A

Since their discovery in 1982, millisecond pulsars have served as exquisite probes of fundamental physics. I will discuss the most transformative current application of millisecond pulsars: the direct detection of gravitational waves. Timing an array of pulsars could result in the detection of a stochastic background of gravitational waves, most likely resulting from an ensemble of supermassive black hole binaries. The unique capabilities of the Allen Telescope Array (ATA) will make it a very important resource for this experiment. The multi-wavelength coverage will increase sensitivity and enable optimal removal of interstellar propagation affects and the flexibility of scheduling afforded by commensal observing will increase the number of sources times and the cadence at which we can observe each source. I will discuss how these properties complement existing facilities and how including the ATA will increase the sensitivity of the international pulsar timing array.

203.04

Ongoing SETI Observation Programs at the ATA Gerald \mbox{Harp}^1

¹SETI Institute. 10:30 AM - 10:40 AM

Ballroom 6A

The Allen Telescope Array is designed for commensal observing with multiple users making spectral images at multiple frequencies and forming real time single-pixel beams in multiple directions at the same time. At the ATA, most SETI observations use beamforming and very high spectral resolution to perform targeted and wide area surveys of the sky, sometimes sharing the observing time with

conventional astronomical observations with the imaging correlator. We shall briefly review several ongoing SETI programs as demonstrations of the capabilities of the ATA.

203.05

Wide-Field Polarimetry and Magnetic Fields Bryan M. Gaensler¹

¹The University of Sydney, Australia. 10:40 AM - 10:50 AM Ballroom 6A

Astrophysical magnetic fields are not directly observable, but we can infer their strength, orientation and structure through observations of radio synchrotron emission and its polarization. The new generation of radio interferometers have two capabilities that make them powerful probes of magnetic fields: wide fields of view with which we can image thousands of discrete radio sources in a single pointing, and broadband spectropolarimetric capabilities with which we can simultaneously measure Faraday rotation towards all of these targets. I will briefly review the polarimetric techniques needed to study magnetic fields both in diffuse gas and in discrete objects such as galaxies and AGN. I will then highlight the innovative new experiments on magnetic fields that the Radio Sky Surveys Project will be able to perform.

203.06

Extragalactic Surveys for Neutral Hydrogen Mary E. Putman¹

¹Columbia University. 10:50 AM - 11:00 AM

Ballroom 6A

The surveys for extragalactic neutral hydrogen will be summarized in this talk with an emphasis on the results from blind HI surveys and the implications for future surveys with the Allen Telescope Array.

203.07

Galaxy Evolution Begins at Home: ATA-256 and Other SKA Pathfinders Snezana Stanimirovic $^{\rm 1}$

¹UW-Madison.

11:00 AM - 11:10 AM

Ballroom 6A

While studies of galaxy evolution generally focus on extensive HI surveys at large redshifts, understanding of detailed physical processes that drive HI evolution in galaxies is equally important. Specifically, we focus on two open questions regarding the very first step in the star-formation cycle in galaxies: How much do galaxy halos flavor and tax the accretion flows that are postulated to bring fresh star-formation fuel to galaxy disks? What are the basic properties of the warm neutral gas, the progenitor of cold star-forming clouds? The very local Universe (The Milky Way and nearby galaxies) offers an unparalleled high-resolution view for answering these questions and ATA-256 and other SKA pathfinders promise great advances.

203.08 Hydrogen 21-cm Cosmology Tzu-Ching Chang¹ ¹ASIAA. 11:10 AM - 11:20 AM

Ballroom 6A

Hydrogen is the most abundant element in the Universe; in its neutral form, the ground state spin-flip 21-cm transition is in principle observable up to very high redshift, z ~ 150, probing a vast volume of the structure in the Universe. Recently, the 21-cm emission has been proposed as a great tool to measure large-scale structure in the "intensity mapping" regime. Specifically, at redshifts around unity, 21-cm intensity mapping can be used to measure the Baryon Acoustic Oscillation (BAO) and thus infer properties of dark energy. I will show recent results of 21-cm cross-correlation measurements at redshift of 0.8, a first step towards such a goal, and the potential of a BAO hydrogen survey that may be achievable with the Allen Telescope Array.

203.09

Joint Opportunities with the RSSP and the Expanded Very Large Array (EVLA) Steven T. Myers¹

¹NRAO.

11:20 AM - 11:30 AM

Ballroom 6A

The Expanded Very Large Array (EVLA, Perley et al. 2009, arXiv:0909.1585) is a program to significantly enhance the capabilities of the VLA through replacement of the receivers, electronics, signal paths, and correlator with cutting-edge technology. When completed in 2012, this upgrade will provide significantly increased continuum sensitivity and spectral survey speeds (by factors of 100 or more in select cases) from 1-50 GHz and in key bands below 1 GHz. Early science observations with EVLA started in March 2010, with increasing capabilities being made available to users over time.

The ATA and the EVLA respectively provide complementary capabilities for low-frequency surveys, and high-frequency coverage plus deep targeted follow-up observations. As a first stage of cooperation, ATA and EVLA will be used to develop key techniques needed to enable future joint RSSP observations, particularly in the area of linked time-domain surveys. In addition, the two instruments will be used in the near term to investigate technical issues related to the development of next-generation radio arrays such as the Square Kilometre Array (SKA).

As increased capabilities become available, a suite of more ambitious Joint RSSP (J-RSSP) observing programs can be undertaken. These projects address science goals central to illuminating the questions posed by Astro2010. A primary J-RSSP target area will be to explore the Dynamic Radio Sky through ATA surveys and prompt EVLA follow-up. The ATA and EVLA are also primary components in a world-wide pulsar timing array as part of the NANOGrav initiative to detect nano-Hertz gravitational waves. Furthermore, J-RSSP studies of the evolution of gas and galaxies and particles and fields through cosmic time will bridge the eras from cosmic dawn to the dawn of new worlds. These and other innovative studies will leverage the considerable capabilities of these two instruments for opening new astronomical horizons this decade and beyond.

204

Large Scale Structure, Cosmic Distance Scale Oral Session *Room 618/620*

204.01

The Cosmic Distance Scale And Growth Rate At Z=0.6 From The Wigglez Dark Energy Survey Chris Blake¹, WiggleZ Dark Energy Survey team ¹Swinburne University of Technology, Australia. 10:00 AM - 10:10 AM

Room 618/620

We present cosmological results from the recently-completed WiggleZ Dark Energy Survey at the Anglo-Australian Telescope. We have obtained spectroscopic redshifts for over 200,000 star-forming galaxies over 1000 square degrees up to redshift z=1. We measure the imprint of baryon acoustic oscillations in the galaxy distribution at the highest redshift to date, and use our detection as a standard ruler mapping the cosmic expansion history. We also exploit redshift-space distortions in the pattern of galaxy clustering to measure the growth rate of cosmic structure across the redshift range z < 1, recovering the first precise measurements in the intermediate-redshift Universe. This combination of cosmic distance and growth measurements allows us to make a powerful self-consistency test of the physical nature of dark energy, spanning the whole epoch for which it is thought to dominate cosmic dynamics.

204.02

Has Baryonic Acoustic Oscillations In The Galaxy Distribution Been Measured? Enrique Gaztanaga¹, A. Cabre²

¹Instituto de Ciencias del Espacio (IEEC/CSIC), Spain, ²Center for Particle Cosmology, University of Pennsylvania.

10:10 AM - 10:20 AM

Room 618/620

Recent publications claim that there is no convincing evidence for measurements of the baryonic acoustic (BAO) feature in galaxy samples using either monopole or radial information. Different claims seem contradicting: data is either not consistent with the BAO model or data is consistent with both the BAO model and featureless models without BAO. We investigate this point with a set of 216 mock realistic galaxy catalogs extracted from MICEL7680, one of the largest volume dark matter simulation run to date. Mocks cover similar volume, densities and bias as the real galaxies and provide 216 realizations of the Lambda Cold Dark Matter (LCDM) BAO model. We find that only 20\% of the mocks show a statistically significant (3 sigma) preference for the true (input) LCDM BAO model as compared to a featureless (non-physical) model without BAO. This indicates that the volume of current galaxy samples is not yet large enough to differentiate between these two different classes of models. Does this mean that we can not measure the BAO position in the mocks? Using a simple (non optimal) algorithm we show that in 50% (100%) of the mocks we can find the BAO position within 5% (20%) of the true value. These two findings are not in contradiction. The former is about model selection, the later is about parameter fitting within a given model. We conclude that current monopole and radial BAO measurements can indeed be used as standard ruler, as long as one assumes the LCDM class of models, or models which produce similar 2-point correlations (and errors) to the ones in LCDM.

204.03D

Structure and Contents of Cosmic Voids: Tests of Cosmology and Gastrophysics

Danny Pan¹, M. S. Vogeley¹

¹Drexel University. 10:20 AM - 10:40 AM

Room 618/620

Using the Sloan Digital Sky Survey (SDSS) we find that voids fill over 60% of the Universe while containing only approximately 10% of the galaxies. The shapes, sizes, and internal structures of voids can be used to determine the cosmological parameters of the Universe, particularly omega-m, sigma-8, omega-L, and the Hubble constant. Additionally, the detailed properties of objects in voids are a strong test of structure formation models. Ly-alpha absorbers from Hubble-STIS quasar absorption line systems are detected in the proximity of galaxies. However, we find that they do not match the underlying galaxy distribution; 60% of Ly-alpha absorbers live in large (R > 10 Mpc/h) cosmic voids.

204.04D

The Baryonic Acoustic Feature and Redshift Distortions in the SDSS and BOSS LRG Samples Eyal Kazin $^{\rm 1}$

¹New York University. 10:40 AM - 11:00 AM Room 618/620

The Baryonic Acoustic Feature in galaxy clustering is one of the most exciting and promising cosmological distance measurements in modern cosmology. I present clustering measurements of the spherically averaged and radial acoustic features in the Luminous Red Galaxy (LRG) sample from the Sloan Digital Sky Survey (SDSS), as well as what might be expected in the (just begun) Baryonic Oscillation Spectroscopic Survey (BOSS).

I will also present results obtained from redshift distortions in galaxy clustering. As galaxies are observed in redshift-space, as opposed to real-space, peculiar velocities strongly affect the line-of-sight clustering signal. By quantifying these distortions, constraints on their progenitor, namely the matter density of the universe Ω_M and the true underlying gravitational theory, may be obtained.

204.05D

Nonlinear Structure Formation: Logarithmic BAO Reconstruction and a Lagrangian Halo Finder Bridget Falck¹, M. C. Neyrinck¹, A. S. Szalay¹

¹Johns Hopkins University.

11:00 AM - 11:20 AM

Room 618/620

Reconstruction has been shown to restore the Baryon Acoustic Oscillation (BAO) peak after it has been degraded by nonlinear structure formation, thereby increasing the precision of the measurement, especially at low redshift. We investigate improving the BAO reconstruction method using a logarithmic approximation of the Lagrangian displacement, instead of the linear Zel'dovich displacement, by calculating the divergence of the displacement field directly in a cosmological nbody simulation. We explore several ways of calculating the divergence and density and discuss their relative merits and shortcomings. We show that the logarithmic approximation holds well into the nonlinear regime, allowing a smaller scale smoothing of the density field in the reconstruction algorithm and thus increasing its effectiveness.

Traditionally a mass particle is thought to enter the nonlinear regime at shell-crossing, where the linear Zel'dovich approximation is no longer valid; the particle will undergo many such crossings as it settles into a halo. We introduce a novel halo-finding algorithm dubbed ORIGAMI that tags halo particles in a simulation according to whether they have crossed paths with their Lagrangian neighbors in a set of orthogonal axes. This gives a definition of halo particles that is independent of a density cutoff, though the grouping of particles into specific halos requires additional refinement. ORIGAMI performs well compared to the standard halo finders and can be extended to a full morphology tagger (halos, filaments, walls, and voids) or act as the first step in another halo grouping algorithm. The authors are grateful for support from the Gordon and Betty Moore and the W.M. Keck Foundations.

204.06

The Geometry Of The Filamentary Environment Of Galaxy Clusters Yookyung Noh¹, J. D. Cohn¹ ¹University of California Berkeley. 11:20 AM - 11:30 AM

Room 618/620

We construct filament catalogues in a 250 Mpc/h N-body simulation using the halo based filament finder of Zhang et al.(2009) to study the properties of filaments in cluster neighborhood. We consider the cluster environment (within 10 Mpc/h spheres) in part because the finder does so. We find the filaments attached to the cluster tend to lie within a 3 Mpc/h thick plane, although often at least one filament lies outside the plane. For many clusters, this planar geometry has a correlation with the line of sight dependent mass scatter in several observables.

205

The Dark Energy Survey Special Session *Room 611/612*

205.01 The Dark Energy Survey Joshua Frieman¹

¹Fermi Nat'l. Accelerator Lab. and U. Chicago. 10:00 AM - 10:10 AM

Room 611/612

The Dark Energy Survey will employ a powerful instrument, the Dark Energy Camera, and a state-of-theart data management system on the improved Blanco 4-meter telescope at CTIO to probe the nature of dark energy and the cause of cosmic acceleration. The instrument includes a 520-Megapixel optical imager with red-sensitive CCDs covering a 3 square degree field of view and an active alignment system. Starting in 2012, using 525 nights over 5 years, the survey will image 300 million galaxies over 5000 square degrees to 24th magnitude and several thousand supernovae over a smaller area, using the grizY passbands. The 120-member international collaboration will use these data to probe dark energy using the galaxy cluster abundance, weak gravitational lensing, baryon acoustic oscillations, and supernovae and carry out studies of strong lensing, galaxy evolution, the structure of the Milky Way, and QSOs, among other topics.

205.02

The Dark Energy Survey Camera (DECam) Brenna Flaugher¹

¹Fermilab. 10:10 AM - 10:20 AM Room 611/612

The Dark Energy Survey (DES) is a next generation optical survey aimed at understanding the expansion rate of the universe using four complementary methods: weak gravitational lensing, galaxy cluster counts, baryon acoustic oscillations, and Type Ia supernovae. To perform the survey, the DES Collaboration is building the Dark Energy Camera (DECam), a 3 square degree, 520 Megapixel CCD camera which will be mounted at the prime focus of the Blanco 4-meter telescope at the Cerro Tololo Inter-American Observatory. The survey will cover 5000 square-degrees of the southern galactic cap with 5 filters (g, r, i, z, Y). DECam will be comprised of 74 250 micron thick fully depleted CCDs: 62 2k x 4k CCDs for imaging and 12 2k x 2k CCDs for guiding and focus. DECam will be used to perform the Dark Energy Survey with 30% of the telescope time over a 5 year period. During the remainder of the time, and after the survey, DECam will be available as a community instrument. Construction of DECam is nearing completion. In order to verify that the camera meets technical specifications for the Dark Energy Survey and to reduce the time required to commission the instrument on the telescope, we have constructed a full sized "Telescope Simulator" and are performing full system testing and integration
prior to shipping to CTIO. An overview of the DECam design and the status of the construction and integration tests will be presented.

205.03

Improvements to the CTIO Blanco Telescope Alistair Walker¹

¹NOAO/CTIO. 10:20 AM - 10:30 AM Room 611/612

The V. M. Blanco 4-m telescope at Cerro Tololo Inter-American Observatory, National Optical Astronomy Observatory, is undergoing a number of improvements prior to the delivery of the Dark Energy Camera. These include improved slewing and tracking performance resulting from a new telescope control system plus new encoders, and upgrades to the primary mirror support system and the environmental control system that have potential to improve both image quality and stability. I will describe the status of the upgrades.

205.04

Processing, Calibration and Archiving for the Dark Energy Survey

Joseph J. Mohr¹, Dark Energy Survey Data Management Team

¹Ludwig Maximilians University, Germany.

10:30 AM - 10:40 AM

Room 611/612

We have developed and tested a high performance computing enabled data management system for the Dark Energy Survey (DES). This highly automated system with built in data quality testing uses a central database at the National Center for Supercomputing Applications to store survey, image and processing metadata that enable automation, provenance tracking and data quality tagging at the image, catalog and object levels. Observed single and multi-epoch catalogs are also stored within the database where they are used during calibration and are available for immediate collaboration access. In addition, periodic data releases involve building new sets of tables that are distributed into external analysis databases that are located at NCSA as well as at Fermilab and other collaboration sites in the US, Brazil, UK, Spain and Germany. Processed images and other file data are distributed to Archive sites throughout the collaboration using high bandwidth grid tools. A set of portals for catalog and image access, for direct manipulation of catalog data within a users own database space, and for operation and monitoring of the data management system itself have been developed and are being used during extensive testing using SDSS scale datasets that are processed, calibrated and then served to the collaboration for scientific and data quality analyses.

The DESDM processing and calibration involves standard image detrending codes that have been specially built for DECam. Astromatic codes (E. Bertin) have been extended for DES and are being used for astrometric calibration, PSF modeling across all images, PSF homogenization during the image stacking and model fitting photometry of all detected objects. Photometric calibration uses both direct calibration for photometric data as well as cross calibration using common objects on overlapping images. Processing also includes shear measurements for all objects and a difference imaging pipeline to search for time variable objects.

205.05

Precision Cosmology with Galaxy Clusters Christopher J. Miller¹, Dark Energy Collaboration (DES), DES Cluster Working Group ¹*University of Michigan.* 10:40 AM - 10:50 AM

Room 611/612

Galaxy clusters probe both the expansion and the rate of growth of structure in the universe. When combined with the results of Type Ia supernovae and baryon acoustic oscillations, and in conjunction with weak lensing, the statistical counting of galaxy clusters will enable tight constraints on the cosmological parameters which describe our Universe. In order to use these cluster counts, we must understand how the clusters are selected, how to measure their masses, and how to statistically compare the counts against the cosmological models. The Dark Energy Survey Cluster Working Group is tackling these issues using a suite of mock galaxy catalogs which closely resemble what will actually be observed for the Dark Energy Survey. Based on these mocks, we present how we are able to fully develop, tune, and test our clustering algorithms, mass calibrations techniques, and cosmological codes prior to any photons entering the Dark Energy Camera.

205.06

Weak Lensing Tomography with DES Bhuvnesh Jain¹

¹University of Pennsylvania. 10:50 AM - 11:00 AM Room 611/612

KOOM 611/612 The Dark Energy Surve

The Dark Energy Survey will provide shape information and photometric redshifts for galaxies over redshifts between 0 and 1. This massive dataset will enable precise measurements of lensing shear correlations and cross-correlations as well as cluster mass calibration. We will discuss current progress in image analysis, shear measurements and prospects for cosmological tests.

205.07

The DES Supernova Survey

Masao Sako¹, Dark Energy Survey (DES) Supernova Working Group, DES Collaboration ¹University of Pennsylvania.

11:00 AM - 11:10 AM

Room 611/612

The Dark Energy Survey (DES) will conduct a dedicated Supernova Survey to discover and obtain multiband light curves of Type Ia supernovae over a broad redshift range of 0.1 &It; z &It; 1. We describe our hybrid survey strategy that targets both high-redshift SN Ia for improved constraints on dark energy, as well as SN Ia at intermediate redshifts to study their physical properties and to obtain a better characterization of systematic uncertainties. We also describe our plans for spectroscopic follow-up observations of the SN candidates and their host galaxies, a major complementary effort that will significantly enhance our overall science goals.

205.08

Large Scale Structure Science with DES

Enrique Gaztanaga¹

¹INSTITUTO DE CIENCIAS DEL ESPACIO (IEEC-CSIC), Spain. 11:10 AM - 11:20 AM Room 611/612

The Dark Energy Survey (DES) will use a new imaging camera on the Blanco 4-m telescope at CTIO to image 5000 square degrees of sky in the South Galactic Cap in five optical bands. I will outline what science we expect from the study of the large scale structure traced by the galaxy distribution in DES. Oscillations of the coupled photon-baryon fluid in the early Universe imprint a "standard ruler" on the galaxy power spectrum. The length of this standard ruler can be calibrated using cosmic microwave background (CMB) anisotropy measurements, in particular from the Planck experiment. Measurements

of the galaxy power spectrum in the transverse and line-of-sight directions then yield values of the angular diameter distance dA(z) and Hubble parameter H(z), respectively. DES experiment can use the broad-band shape of the power spectrum in addition to the oscillation wavelengths themselves, at the price of somewhat stronger model dependence. Redshift space distortions and cross-correlation can also provide valuave information on cosmological parameters.

206

Science Highlights from NASA's Astrophysics Data Analysis Program II Special Session *Room 615/617*

206.01

Mapping the Hot Gas in the Galaxy with XMM-Newton

David B. Henley¹, R. L. Shelton¹, K. Kwak¹, M. R. Joung², M. Mac Low³ ¹Univ. Of Georgia, ²Columbia University, ³AMNH. 10:00 AM - 10:15 AM

Room 615/617

The Galaxy is permeated by gas with a temperature between 1 and 3 million K. This X-ray-emissive gas makes a significant contribution to the diffuse soft X-ray background (SXRB), particularly at high Galactic latitudes. By measuring the spectrum of the SXRB emission, we can determine the physical conditions in the hot gas, and thereby constrain its origin and evolution.

We present results from a survey of the SXRB that we are carrying out using archival XMM-Newton observations. We do not restrict ourselves to blank-sky observations, but instead use as many observations as possible, removing bright or extended sources by hand if necessary. We present measurements of the SXRB O VII and O VIII intensities extracted from several hundred XMM-Newton observations. The variation of these intensities over the sky helps constrain the distribution of hot gas in the Galaxy, while for directions with multiple observations, the time variation of the intensities can be used to constrain models of solar wind charge exchange (SWCX) emission. In addition, we present measurements of the Galactic halo temperature and emission measures extracted from a subset of our observations. These observations were chosen as they are expected to have the smallest levels of SWCX contamination. By comparing these measurements with the predictions of hydrodynamical models, we can strongly rule out a model in which the hot halo gas seen with XMM-Newton resides in isolated extraplanar supernova remnants. Instead, we find that the halo X-ray surface brightness above 0.4 keV is likely dominated by emission from a supernova-driven galactic fountain, although we cannot rule out the possibility that an extended halo of accreted material also contributes.

This work is supported by NASA grant NNX08AJ47G, awarded through the Astrophysics Data Analysis Program.

206.02

Reanalyzing COMPTEL Data: The Gamma-Ray Sky up to 50 MeV Andreas C. Zoglauer¹

¹University of California at Berkeley.

10:15 AM - 10:30 AM

Room 615/617

A decade after de-orbiting CGRO, COMPTEL's 1-30 MeV all-sky imaging data set remains unsurpassed, and no current or planned mission is capable of challenging COMPTEL's performance in the near future. Since the nineties, when the original COMPTEL data analysis techniques were developed, the performance of state-of-the-art computers has increased by orders of magnitude, enabling new and improved techniques that were out of reach at that time. These techniques include Geant4 simulations,

Bayesian event selections, and partially-binned-response list-mode ML-EM imaging techniques. Besides others, the new methods offer the possibility to extend COMPTEL's upper energy limit from 30 to 50 MeV. The high energy range (above ~10 MeV) is particularly challenging due to the low scattering cross-section for Compton telescopes and the coarse angular resolution of standard pair-conversion telescopes such as FERMI. First results in the energy range from 30 to 50 MeV are promising: Using COMPTEL data through November 1997, the Crab pulsar can be detected with 6-7 sigma and an angular resolution of ~1.6 degrees is achieved. In this presentation we report on the analysis methods and present results from various strong gamma-ray sources in the high energy band from 10 to 50 MeV and compare them to the original COMPTEL results.

206.03

PRIMUS: Redshifts for 140,000 Galaxies to z~1

John Moustakas¹, PRIMUS Collaboration ¹University of California, San Diego.

10:30 AM - 10:45 AM

Room 615/617

The elapsed time since $z\sim1$, spanning roughly 60% of the age of the Universe, represents an important and dramatic epoch in galaxy evolution. During this time galaxies agglomerate into large-scale structures like groups and clusters, the cosmic rate of star formation declines by an order-of-magnitude, and there is a significant buildup in the population of red, passively evolving galaxies. However, efforts to understand this evolution by leveraging the tremendous multiwavelength datasets acquired from space -- from Spitzer, GALEX, Chandra, XMM, and HST -- have been hampered by a lack of precise redshifts for large samples of galaxies over a wide enough area of the sky to mitigate the effects of cosmic variance. To address these issues, we have carried out the PRIsm MUlti-object Survey (PRIMUS), the largest spectroscopic survey of intermediate-redshift galaxies conducted to date. Combining redshifts from PRIMUS with ancillary ground- and space-based observations from the X-ray to the infrared, we have begun to measure the relative importance of large-scale environment on galaxy evolution, and the multivariate distributions of luminosity, color, star formation rate, stellar mass, and AGN activity in galaxies since $z\sim1$ with unprecedented precision. We introduce the survey and highlight the first science results from PRIMUS. PRIMUS is generously supported by grants from NASA and NSF.

206.04

Finding All the Quasars with GALEX, Even the Ones GALEX Doesn't Detect!

David W. Hogg¹, J. Bovy¹, D. Schiminovich²

¹New York University, ²Columbia University.

10:45 AM - 11:00 AM

Room 615/617

Traditional "catalog matching" fails when two imaging surveys of very different depth, resolution, or wavelength are being compared, especially for the bulk of sources, which are faint. When there is asymmetry (one survey substantially better than the other in resolution and signal-to-noise), forced photometry in the less-good data set is much to be preferred. The output of such photometry permits "stacking" and other activities that make non-detects just as scientifically valuable as the significant detections. We show that we can enormously improve spectroscopic target selection based on SDSS data by making use of forced photometry in the GALEX pixels, for finding low-redshift (UV-bright), high-redshift (UV-faint), and He-II emitting (high-redshift but anomalously UV-bright) quasars, among many other things.

206.05 The Relationship Between AGN Spectral Energy Distributions and Feedback Gordon T. Richards¹

¹Drexel Univ.. 11:00 AM - 11:15 AM

Room 615/617

A large body of recent work points towards feedback processes related to the active accretion of matter onto supermassive black holes in the centers of most massive galaxies as being one of the primary regulatory processes for pc to Mpc scales in the Universe. We seek to close the gap in our knowledge of the physics behind active galactic nuclei (AGN) feedback processes by improving in our knowledge of 1) the spectral energy distribution (SED) of AGNs from the mid-IR through UV and 2) the relationship between the SED and the accretion disk wind. Using a sample of up to 30,000 SDSS quasars, we explore the range of properties exhibited by high-ionization, broad emission lines, such as CIV (specifically the Baldwin effect and the

``blueshifting'' of the high-ionization emission lines). We consider these phenomena within the context of an accretion disk wind model that is modulated by the shape of the SED. Composite spectra are constructed as a function of CIV emission line properties in attempt to reveal empirical relationships between different line species and the SED. Within a two component disk+wind model of the BELR where the wind filters the continuum seen by the disk component, we find that radio-loud quasars are dominated by the disk component, while broad absorption line quasars are dominated by the wind component. Our results suggest that there could be significant systematic errors in the determination of L_{Bol} and black hole mass that make it difficult

to place these findings in a more physical context. However, it is possible to classify quasars in a paradigm where the diversity of broad emission line region parameters are due to changes in an accretion disk wind between quasars (and over time) that are underlied by the SED, which ultimately must be tied to mass and accretion rate.

206.06

Tidal Disruption Events and Event Rates Based on a X-Ray Survey of Rich Galaxy Clusters Peter Maksym¹, M. Ulmer¹, M. Eracleous²

¹Northwestern University, ²Pennsylvania State University.

11:15 AM - 11:30 AM

Room 615/617

When a star passes sufficiently close to a massive black hole, it may be torn apart by the tidal forces. The shock heating and subsequent accretion of the stellar debris produces a luminous, super-Eddington flare thought to be brightest at X-ray and ultraviolet wavelengths. Tidal flares and the rate at which they occur provide an unusual probe of the black hole mass distribution function of otherwise inactive galaxies, as well as the populations and dynamics of the nuclei of such galaxies, with implications for galaxy evolution models and gravitational wave detection.

We have examined a number of galaxy clusters using archival observations primarily using XMM-Newton and Chandra and present examples of candidate tidal disruption flares, and discuss our determination of the disruption rate. Although these tidal disruption events are rare (approximately once per galaxy per 10⁴ years), our archival X-ray study of galaxy clusters has allowed us to add to the still relatively small number of known events, constrain the disruption rate, and help set the stage for future wide-field and synoptic searches such as by eRosita and LSST. We have found two such events from our early studies of only two well-sampled clusters. Hence, in our continuing studies of dozens of rich clusters, we anticipate identifying and confirming many more tidal flares. This research will significantly impact our understanding of tidal flares, the rate at which they are produced, and which galaxies produce them. This research has been by NASA ADP grant NNX08AJ35G.

207 *M31, M32 & S4G Spirals* Oral Session *Room 4C-2*

207.01

Bayesian Modeling of Andromeda's Giant Stellar Stream

Mark A. Fardal¹, M. D. Weinberg¹

¹University of Massachusetts. 10:00 AM - 10:10 AM

Room 4C-2

Observed stellar streams and other tidal structures in galaxies are often difficult to model analytically, and best tackled with N-body simulations. But use of one to a few such simulations often fails to capture the range of possibilities presented by the data. Here we apply the Bayesian Markov Chain Monte Carlo (MCMC) method to previous observations of M31's giant stellar stream (GSS). We constrain the stream progenitor's orbital path and phase, its luminous and dark mass, and M31's halo mass. We discuss pitfalls of the MCMC approach arising from the intrinsic noise in N-body simulations, and techniques useful in avoiding these pitfalls. Using the GSS as an example, we also show how the data-constrained libraries of models generated by this method can be used to objectively compare different model spaces and make testable predictions.

207.02

Keck Spectroscopy of M31's HST/MCT Region. II: Kinematical and Spectral Characteristics of Stellar Subpopulations

Puragra Guhathakurta¹, C. E. Dorman¹, K. M. Howley¹, J. Bullock², J. Cuillandre³, J. Dalcanton⁴, K. Gilbert⁴, J. Kalirai⁵, A. Kniazev⁶, A. Seth⁷, B. Williams⁴, SPLASH collaboration, PHAT collaboration ¹UC Santa Cruz, ²UC Irvine, ³CFHT, ⁴U Washington, ⁵STScl, ⁶SAAO, South Africa, ⁷Harvard/CfA. 10:10 AM - 10:20 AM

Room 4C-2

Trends in stellar kinematics in the inner regions of the Andromeda galaxy (M31) offer insight into the structure and formation of spiral galaxies. The synthesis of the SPLASH (Spectroscopic and Photometric Landscape of Andromeda's Stellar Halo) and PHAT (Panchromatic Hubble Andromeda Treasury) collaborations offers an unprecedented opportunity to understand the interplay between the assembly, star formation, and chemical enrichment histories of large disk galaxies.

This paper presents a preliminary exploration of the synergy between Keck/DEIMOS spectra and highresolution multiband HST photometry. The PHAT observations consist of ACS/WST imaging in two optical filters, WFC3/UVIS imaging in two ultraviolet filters, and WFC3/IR imaging in two NIR filters. While the PHAT survey intends to cover a large contiguous region in M31's eastern quadrant, the Year 1 data obtained so far provide only limited spatial/spectral coverage. Various subpopulations of stars identified in this limited region are targeted for Keck spectroscopy: hot massive main-sequence stars; intermediate-age AGB stars; metal-poor intermediate-metallicity and metal-rich red giants; planetary nebulae; and X-ray sources (X-ray binaries, background QSO/AGNs, etc.) We present a comparison of the kinematical and spectroscopic characteristics of these stellar subpopulations. Funding for this project was provided by NASA and NSF.

207.03

Keck Spectroscopy of M31's HST/MCT Region. I: Stellar Kinematics of the Disk and Bulge Claire Dorman¹, K. M. Howley¹, P. Guhathakurta¹, J. Bullock², J. Consiglio¹, J. Cuillandre³, J. Dalcanton⁴, K. Gilbert⁴, J. Kalirai⁵, A. Seth⁶, B. Williams⁴, B. Yniguez², SPLASH collaboration, PHAT collaboration ¹UC Santa Cruz, ²UC Irvine, ³CFHT, ⁴U Washington, ⁵STScI, ⁶Harvard/CfA. 10:20 AM - 10:30 AM

Room 4C-2

Trends in stellar kinematics in the inner regions of the Andromeda galaxy (M31) offer insight into the structure and formation of spiral galaxies. The synthesis of the SPLASH (Spectroscopic and Photometric Landscape of Andromeda's Stellar Halo) and PHAT (Panchromatic Hubble Andromeda Treasury) collaborations offers an unprecedented opportunity to understand the interplay between the assembly, star formation, and chemical enrichment histories of large disk galaxies.

We present a Keck/DEIMOS multislit spectroscopic study of the resolved red giant star population in the southern and eastern quadrants of M31. Targets are selected from two overlapping

astrometric/photometric catalogs: the ground-based CFHT/MegaCam 2 deg x 2 deg mosaic image, and existing Year 1 PHAT survey data embedded within the area of the CFHT mosaic. Radial velocities are measured for about 5000 red giant stars, and for ambient ionized gas in M31, the latter being an unexpected byproduct of this study. The 2D pattern of stellar velocities are compared to a simple model with two components: one with high v_{rot} /sigma associated with an exponential disk and one with low v_{rot} /sigma associated with a Sersic bulge. A detailed comparison is carried out between the kinematics of the stellar disk and that of the ionized gas, the latter plausibly associated with M31's star-forming thin disk.

Our study will ultimately address questions such as: How dynamically hot is the stellar disk of M31? Is there evidence for a distinct thick disk? What are the roles of heating and accretion in the formation of stellar disks?

This research was supported by NASA and NSF.

207.04D

The Splash Survey: Internal Stellar Kinematics of the Nearby Compact Elliptical M32

Kirsten Howley¹, P. Guhathakurta¹, M. Geha², J. Kalirai³, R. van der Marel³, B. Yniguez⁴, J. Cuillandre⁵, K. Gilbert⁶

¹UCSC, ²Yale University, ³Space Telescope Science Institute, ⁴UC Irvine, ⁵Canada-France-Hawaii Telescope, ⁶University of Washington.

10:30 AM - 10:50 AM

Room 4C-2

M32, a satellite of the Andromeda (M31) galaxy, is our nearest example of the rare and enigmatic compact elliptical galaxy type. It has long been known that the outer isophotes of M32 are distorted; this is presumed to be caused by its tidal interaction with M31. In this paper, new Keck/DEIMOS spectroscopic observations are presented of the integrated light (r < 100") and, for the first time, resolved stellar population (100" < r < 200") of M32 (where M32's I-band $r_{eff} = 29$ " = 0.1 kpc). Our measurement of the rotation curve and velocity dispersion profile extend beyond M32's tidal distortion radius of r ~ 150", in contrast to previous kinematical studies that went out to r ~ 30". Studies of M32 are made challenging by the fact that the galaxy is projected against the bright/complicated inner region of M31. This, combined with the steeply falling brightness profile of M32, implies that resolved stellar population studies are caught between a rock and hard place: crowding/blending is severe in the inner parts while M31 contamination is severe in the outer parts. In the resolved stellar population portion of our study, we use spatial and kinematical information to statistically account for M31 contamination. Unlike NGC 205, another close neighbor of M31, M32's kinematics appear to be regular and symmetric

and do not show obvious sharp gradients across the tidal distortion region. This lack of a strong gradient will serve as a constraint on tidal interaction models. This work is funded through the NSF and NASA.

207.05

Grand Design and Flocculent Spirals in the Spitzer Survey of Stellar Structure in Galaxies (S4G) Debra M. Elmegreen¹, S4G Team

¹Vassar College.

10:50 AM - 11:00 AM

Room 4C-2

The shapes and strengths of arms in spiral galaxies provide insight into their formation. In optical bands, grand design galaxies show distinct differences in their arms compared with flocculent galaxies; they have long, symmetric, continuous arms with strong contrast over the interarm regions, while flocculent galaxies have short arm pieces and small contrasts. Such differences are evident in near-infrared images as well. Here we extend the study of arm structure to the mid-infrared with a sample of 50 galaxies from the Spitzer Survey of Stellar Structure in Galaxies (S4G) in order to examine the strengths and appearances of spiral arms at 3.6 and 4.5 microns; these bands trace the bulk of the underlying mass distribution without confusion from dust obscuration. We show symmetric components through image rotation, and measure arm-interarm contrasts for individual arms and Fourier components over the whole galaxy. We find that grand design galaxies have stronger arms than multiple arm or flocculent spirals even at mid-infrared wavelengths, suggesting that density waves are not significant in the latter. The peak Fourier components have higher values in barred galaxies with longer bars.

207.06

Bar Frequency & Galaxy Host Properties using the Spitzer Survey of Stellar Structure in Galaxies (S4G) Kartik Sheth¹, T. Mizusawa¹, T. Kim², J. Munoz-Mateos¹, M. W. Regan³, B. de Swardt⁴, D. Gadotti⁵, S4G Team

¹NRAO, ²NRAO / Seoul National University, ³STScI, ⁴SAAO, South Africa, ⁵ESO, Chile.

11:00 AM - 11:10 AM

Room 4C-2

Using the volume limited sample of 2,331 nearby galaxies from the Spitzer Survey of Stellar Structure in Galaxies (S4G), we have classified the frequency of barred spiral galaxies. The literature abounds with frequency ranges from as low as 20% to as high as 80% but these variations are driven by the quality of the data, the sample size and the methodology of the studies. Using the 3.6 and 4.5 micron IRAC images from S4G, we are able to make a definitive measurement of the local bar fraction as a function of the galaxy host and environment. We present the results from this survey and discuss how the current bar fraction compares to the declining frequency of bars from the present day to z~1.

207.07

The S4G View of Stellar Mass Distributions, Mid-IR Dust, and Evolved, Intermediate-age Stars Sharon Meidt¹, S4G Team

¹MPIA, Germany.

11:10 AM - 11:20 AM

Room 4C-2

We describe a technique for constructing accurate 2D maps of the stellar mass distribution in nearby galaxies from S4G 3.6 micron images, for extension to the full S4G sample. To isolate the old stellar light from contaminant emission (e.g. hot dust and the 3.3 PAH feature) in the IRAC 3.6 and 4.5 micron bands we use an ICA technique (fastICA; Hyvarinen 1999 and Hyvarinen & Oja 2000) designed to separate statistically independent source distributions. The technique also removes emission from low mass-to-light evolved objects, such as AGB and RSG stars, leaving a clean, smooth map of the underlying old

distribution of light. Final stellar mass maps (post application of a stellar M/L_{3.6} assigned by the [3.6]-[4.5] color) retain a high degree of structural information and compare well in total mass to other techniques. Within the context of mass and age estimation via SED modelling at high z, we also extract optical-to-mid-IR SEDs of the AGB-dominated, i.e. ~1 Gyr old, populations located via ICA-assisted identification, and constrain the typically uncertain fractional contribution of AGB light to the total stellar emission in (rest-frame) NIR bands that plagues age and mass estimation in high z studies.

207.08

Tidal Debris of Early Type Galaxies in the Spitzer Survey of Stellar Structure in Galaxies (S4G) Taehyun Kim¹, S4G Team

¹NRAO/SNU. 11:20 AM - 11:30 AM

Room 4C-2

With the 3.6 micron image of early type galaxies (T <-1) drawn from the Spitzer Survey of Stellar Structure in Galaxies (S4G), we perform two-dimensional modeling of galaxy light distributions to investigate tidal debris of early type galaxies such as shells and tidal tails. We find that about 10% of our sample galaxies show tidal features and 90% of those galaxies have late type (T > 1) companion galaxy. The physical

distances estimated from redshifts between those galaxies range from 70 kpc to 800 kpc. These tidal features contribute $5\% \simeq 15\%$ to the total 3.6 micron luminosity. We present the structural properties of these galaxies and discuss how they deviate from normal early type galaxies.

209

Practical Tools & Techniques for Educators Oral Session *Room 606*

209.01

Tapping the Power of an Online Course to Allow for Differentiated Introductory Astronomy Instruction Richard Gelderman $^{\rm 1}$

¹Western Kentucky Univ.. 10:00 AM - 10:10 AM

Room 606

Online classes are here to stay. This appears to be true regardless of whether or not student performance in online environments is really comparable to performance levels in comparable face-to-face instruction (e.g., Ury & Ury 2005, Slater & Jones 2004, Brown & Liedholm 2002). This report avoids that unwieldy question and instead concentrates on the opportunities for online courses to build on their potential to improve upon standard classroom settings. An introductory astronomy course has been designed that utilizes MasteringAstronomy and Blackboard to provide a course structure that varies depending on the results of pre-tests and quizzes. Software flags unlock additional tutorials and formative assessments for students who perform poorly on the pre-tests and gatekeeper quizzes. This "long track" involves no grade penalty, but does require additional time on task. While some students withdraw in frustration, the majority of students who find themselves on the "long track" express appreciation at being encouraged to finally learn the material. Meanwhile, the high performing students proceed quickly toward the unit exams, completing their work fairly quickly but tending to spend more time interacting within the Discussion Forums. Overall, this ability to provide differentiated instruction is a meaningful improvement over instructional approaches that can be implemented in a large enrollment face-to-face classroom.

Brown, B. & Liedholm, C., 2002, Am. Economic Review, 92, 444

Slater, T. & Jones L., 2004 Astronomy Education Review, 3(1) Ury, G. & Ury, C., 2005, Proc ISECON, 22

209.02

The Life And Death Of Bob (a.k.a. Ngc 6397) In An Introductory College-level Astronomy Class For Nonscience Majors

C. Renee' James¹

¹Sam Houston State Univ.. 10:10 AM - 10:20 AM Room 606

We describe the use of Bob (a.k.a NGC 6397) as a conceptual anchor for a semester of "Stars and Galaxies," an introductory college-level astronomy course for non-science majors. NGC 6397 is a Hubble Heritage image, and with a variety of stellar temperatures evident in the colors, it makes a great starter image for a stars and galaxies class. As the semester progresses and student knowledge grows, the same cluster can be used to explore the topics of sizes, temperatures, luminosities, masses, distances, magnitudes, spectral types, HR Diagrams, stellar evolution, determination of cluster age, white dwarfs, blue stragglers... Virtually the entire "stars" part of the "Stars and Galaxies" class can derive from this single example, which anchors student learning to a familiar object throughout the semester. Example discussion questions and personal response (voting) questions are provided, along with comments about the structure of class, assessments, Bob's funeral, and the educational soundness of this approach. We seek collaboration with astronomy educators who would like to adopt "Bob" so that we may gauge whether this approach is measurably different from a more traditional format. "The Life and Death of Bob" was awarded a Gold Star by the Institute for Global and Environmental Strategies in July, 2010, for inspiring uses of Hubble in education.

209.03

Celestial Navigation for the Novice Philip M. Sadler¹

¹Harvard-Smithsonian, CfA. 10:20 AM - 10:30 AM Room 606

What kinds of astronomical lab activities can introductory astronomy students carry out easily in daytime? The most impressive is the determination of their latitude and longitude from observations of the sun. The "shooting of a noon sight" and its "reduction to a position" is a technique still practiced by navigators in this age of GPS. Indeed, the U.S. Coast Guard exams for ocean-going licenses and include celestial navigation. These techniques continue to be used by the military and by private sailors as a backup to electronic navigation systems. We present a method to establish one's latitude and longitude to better than 30 miles from measurements of the sun's altitude that is easily within the capability non-science majors. This is a practical application of astronomy in use the world over. The streamlined method used is based on an easy-to-build protractor and string quadrant. Participants will leave with all materials to conduct this activity in their own classroom.

209.04 Developing a STEM Education Pipeline Using Astronomy and Space Science Michael Gibbs¹ ¹Capitol College. 10:30 AM - 10:40 AM

Room 606

The Capitol College Center for Space Science Education and Public Outreach is in its second year of operation working to address the clearly articulated national need of providing an educated workforce in the science, technology, engineering and math (STEM) fields. Working with the K-12, community college and college students, the Center is actively engaged in providing learning opportunities for future leaders in STEM. This goal is accomplished through the following methods:

1.Increase student awareness of selected astronomy/space science career fields that require a college education, including necessary academic preparation related to STEM courses in high school.

2.Increase the number of community college students, specifically within the traditionally underrepresented populations, advance to the bachelor's level degree within the STEM fields and then secure jobs within the field.

3.Increase STEM participation/majors in general (both in community colleges and four-year colleges), and especially NASA-related disciplines.

This presentation provides an update regarding the Center's activities, reports on the year-one results working with middle schools and high schools in the state of Maryland and the Prince George's Community College, and highlights plans for the future.

209.05

Beyond Earth: Weaving Science and Indigenous Culture - A 1-year NSF Planning Grant Timothy Young¹, M. Guy¹, C. Baker Big-Back², K. Froelich³

¹Univ. of North Dakota, ²Fort Berthold Community College, ³Sitting Bull College. 10:40 AM - 10:50 AM

Room 606

We present results of a 1-year NSF planning grant called Beyond Earth. The project is designed to engage Native American, urban, and rural families in science learning while piloting curriculum development and implementation that incorporates both Native and Western epistemologies. Physical, earth, and space science content is juxtaposed with indigenous culture, stories, language and epistemology in after-school programs and teacher training. Project partners include the Dakota Science Center, Fort Berthold Community College, and Sitting Bull College. The Native American tribes represented in this initiative illustrate partnerships between the Dakota, Lakota, Nakota, Hidatsa, Mandan, and Arikara.

Over the past year the primary project deliverables include a culturally responsive curriculum Beyond Earth Moon Module, teacher training workshops, a project website. The curriculum module introduces students to the moon's appearance, phases, and positions in the sky using the Night Sky Planetarium Experience Station to explore core concepts underlying moon phases and eclipses using the interactive Nature Experience Station before engaging in the culminating Mission Challenge in which they apply their knowledge to problem solving situations and projects. The Native Science and Western Science activities developed, planetarium explorations created, and website toolkit utilizations are presented.

209.06

Assessing Workshop Models for Informal Educators: ASP's "Astronomy from the Ground Up" Experiment.

Jim Manning¹, S. Gurton¹, A. Hurst Schmitt¹, S. Pompea², M. Glass³, K. Haley⁴ ¹Astronomical Society of the Pacific, ²NOAO, ³ASTC, ⁴ILI. 10:50 AM - 11:00 AM *Room 606* The classic workshop model for science educators in the past has been largely in situ: you show up somewhere, meet your fellow workshoppers, get personal treatment from instructors over several intensive days of content delivery, illustrative activities, and practice in technique, and try to incorporate what you've learned once you get back. But in an age when everybody's digitally connected, and many can't afford to travel, can an "online" workshop be as effective? This was a key question in the Astronomical Society of the Pacific (ASP) NSF-funded project "Astronomy from the Ground Up," designed to increase astronomy education capacity at small and medium-sized science and nature centers and museums around the U.S. Together with its institutional partners, the Association of Science and Technology Centers (ASTC) and the Institute for Learning Innovation (ILI), and a cadre of individual partners, the ASP conducted both on-site and online workshops and created an online community of practice to increase informal educator capacity to present astronomy to their audiences, and to evaluate the relative effectiveness of the on-site and online delivery schemes. The presenter(s) will share some initial results and findings of the project.

209.07

Teacher Professional Develpment That Meets 21st Century Science Education Standards Wil E. van der Veen¹, T. Roelofsen Moody¹

¹New Jersey Astronomy Center.

11:00 AM - 11:10 AM

Room 606

The National Academies are working with several other groups to develop new National Science Education Standards, with the intention that they will be adopted by all states. It is critical that the science education community uses these new standards when planning teacher professional development and understands the potential implementation challenges.

As a first step in developing these new standards, the National Research Council (NRC) recently published a draft Framework for Science Education. This framework describes the major scientific ideas and practices that all students should be familiar with by the end of high school. Following recommendations from the NRC Report *"Taking Science to School" (NRC, 2007),* it emphasizes the importance of integrating science practices with the learning of science content. These same recommendations influenced the recently revised New Jersey Science Education Standards. Thus, the revised New Jersey standards can be valuable as a case study for curriculum developers and professional development providers.

While collaborating with the New Jersey Department of Education on the development of these revised science standards, we identified two critical needs for successful implementation. First, we found that many currently used science activities must be adapted to meet the revised standards and that new activities must be developed. Second, teacher professional development is needed to model the integration of science practices with the learning of science content.

With support from the National Space Grant Foundation we developed a week-long Astronomy Institute, which was presented in the summers of 2009 and 2010. We will briefly describe our professional development model and how it helped teachers to bridge the gap between the standards and their current classroom practice. We will provide examples of astronomy activities that were either adapted or developed to meet the new standards. Finally, we will briefly discuss the evaluation results.

209.08

The Pulsar Search Collaboratory: Three Years of Discovery Maura McLaughlin¹, S. Heatherly², R. Rosen² ¹West Virginia University, ²NRAO. 11:10 AM - 11:20 AM

Room 606

The Pulsar Search Collaboratory (PSC) is a joint partnership between the National Radio Astronomy Observatory (NRAO) and West Virginia University (WVU) to improve the quality of science education in West Virginia high schools. The ultimate goal of the PSC is to engage students in science, technology, engineering, mathematics (STEM), and related fields by using information technology to conduct current scientific research, specifically searching for new pulsars. We expect to discover roughly 30 new pulsars in the PSC data.

The PSC has had several scientific and educational successes. To date, the PSC students have made two astronomical discoveries: a 4.8-s pulsar and bright radio burst of astrophysical origin, most likely from a sporadic neutron star. We have 21 new high schools this year, bringing the number of PSC schools to 43. Ten of these schools are part of PSC West, a trial scale-up of our original PSC program. Of the 33 schools in the original PSC program, 13 come from rural school districts; one third of these are from schools where over 50% participate in the Free/Reduced School Lunch program. We are reaching first generation college-goers. For students, the program succeeds in building confidence in students, rapport with the scientists involved in the project, and team-work ability. We see additional gains in girls, who see themselves as scientists after participating in the PSC program. This is an important predictor of success in STEM fields.

210

HAD VI History of Astronomy Oral Session Room 613/614

210.01

A Fascinating Phase In Solar Science: The Rise And Fall Of Schaeberle's Mechanical Theory Of The Solar Corona

John C. Pearson¹, W. Orchiston¹ ¹James Cook University, Australia. 10:00 AM - 10:15 AM Room 613/614

Nearing the end of the late nineteenth century, John Martin Schaeberle, a staff astronomer at the Lick Observatory, wondered about the forces necessary to create the visual apparition of the solar corona. Homebound from the December 1889 eclipse, he laid the ground work for a new theory to explain the intricate coronal details and broad forms that he observed from numerous composite drawings and photographs from the January 1889 eclipse. In 1891, he published his *A Mechanical Theory of the Solar Corona* which attracted a diverse group of followers.

This paper will highlight Schaeberle's theory as it evolved, which was then subjected to tests and intense scrutiny, and finally proven wrong.

210.02

The Boyden Station At Arequipa, Peru: Astrophysics On A Tight Budget Thomas R. Williams $^{\rm 1}$

¹Independent Scholar. 10:15 AM - 10:30 AM Room 613/614

The history of the Harvard College Observatory includes Edward Charles Pickering's ambitious plan to catalogue the night sky in terms of standardized photometry and spectral classification of all stars in both the Northern and Southern celestial hemispheres. In 1890, Pickering established the HCO's Boyden Station at Arequipa, Peru, to provide the raw material from which to construct those catalogues. This

paper will consider the operation of the Boyden Station during the first two decades of the twentieth century with particular emphasis on the period during which Leon Campbell supervised the station, and reflect on the consequences of Pickering's scientific agenda, management style and budgetary constraints as reflected by that operation.

William A. Fowler and Grote Reber were born in 1911, grew up in the American Midwest, and started

academic nor biological descendants. Despite their different styles, both the radio engineer and the

210.03

On the Centennial of Willy Fowler and Grote Reber: It Takes All Kinds

Joseph S. Tenn¹

¹Sonoma State Univ.. 10:30 AM - 10:45 AM Room 613/614

out studying engineering. Neither ever made professional use of optical telescopes, and initially neither considered himself an astronomer. Reber was a radio engineer who followed up on Karl Jansky's surprising discovery of radio emissions from the sky by building his own radio telescope, and for several years he was the world's only radio astronomer. His discoveries showed that much new information could be obtained about the Universe by detecting and analysing what he called "cosmic static". Fowler was a nuclear physicist who took over leadership of a group at Caltech begun by C.C. Lauritsen and made the Kellogg Radiation Lab the world's leading site for learning about the reactions that power the stars and produce all but the lightest elements. He devoted most of his time in his later years to theoretical work in nuclear astrophysics. Personally, the two were quite different: Fowler, who spent more than sixty years at Caltech, was an insider, an influential member of many committees and organizations, and a president of the American Physical Society. Reber was an outsider who hardly ever worked with others and did nearly all of his astronomical research as an amateur. Fowler left more than 50 Ph.D. students, many postdoctoral fellows, two children, and a grandchild. Reber left neither

nuclear physicist made enormous contributions to twentieth century astronomy.

210.04

Decades of Decision, Delight, and Despair

Virginia L. Trimble¹ ¹UC Irvine & LCOGT.

10:45 AM - 11:00 AM

Room 613/614

By the time this is presented, the results of the 6th decadal survey ("The Blandford Report") will be known. Meanwhile, I have re-read the first five (Whitford, Greenstein, Field, Bahcall, McKee-Taylor) and endeavored to determine just which of the things they asked for we eventually got (HST, the VLA), which we did not (more common-used optical telescopes, a large deployable reflector in space), which things we got that no one seems to have asked for, and which might yet happen (JWST, Con-X now part of IXO). Prioritizing facilities also inevitably prioritizes science, and something will be said about how subtopic emphasis has shifted, about the structure and demographics of the review panels themselves (whose total size peaked at 300+ for the Bahcall report), and about the demographic predictions made by the panels.

210.05

Alignments of Sun and Moon Create the Driving Force Behind Storms - But also Earthquakes? Bella Chao Chiu¹

¹*MIT.* 11:00 AM - 11:15 AM

Room 613/614

Our work started with explaining the storms in the Pacific, known as El Nino and La Nina. It was the alignment of sun and moon, pulling together about twice a month. Often a solar eclipse path will show more clearly where the bodies are. Then, during this last year, the same point of view has surprisingly shed light on the problem of earthquake prediction. The events which caught our attention began with the El Nino storm of February 23, 1998. Since we are solar eclipse watchers, we noticed the long eclipse path of February 26th, 1998, which ran through Panama and parts of Columbia and Venezuela. Calculations showed that the gravity of the sun would add 46% of tidal force to that of the moon. Descriptions of this storm (and others) have convinced us that the coming together of sun and moon is the driving force behind the storms known as the El Nino and La Nina in the Pacific Ocean. Then in 2004, we had the earthquake in Indonesia which produced a great tsunami. And we head from and read about the effects of great current changes, or tides, which can trigger earthquakes. So far, the tide scientists say that tidal forces affect only shallow earthquakes. But is there now an increase in depth in ocean, or in frequency, due to global warming?

Earhquake specialists had already calculated there is a greater than 90% probability of the major earthquake occurring within the next 30 years. This is for Los Angeles and San Francisco, and a similar situation for Japan. Now we can close in on what days the probabilities are higher.

211

Evolution of Galaxies III Oral Session *Room 607*

211.01D

Red Nuggets at z>1: The Structure of Early-type Galaxies Over Cosmic History Ivana Damjanov $^{\rm 1}$

¹University of Toronto, Canada. 10:00 AM - 10:20 AM Poom 607

Room 607

The size growth of massive passively evolving galaxies from redshifts beyond z~1 has been the source of much puzzlement and debate in recent years. I will present the results of an HST (ACS F814W + NICMOS F160W) imaging survey of 55 massive passively evolving GDDS galaxies at 0.6 < z < 2, confirming that the large fraction (\sim 30%) of the massive red objects at z > 1.2 are extraordinarily compact, with effective radii under one kiloparsec. Similar objects seem to be less abundant at z < 1 - less than 10% of these objects are as compact as their higher redshift massive counterparts. Furthermore, compact massive galaxies are completely absent in the local Universe. To better understand the underlying phenomenon behind this change in size, we define a 'stellar mass Kormendy relation' (stellar mass density vs. size) to isolate the effects of size evolution from those of luminosity and color evolution in stellar populations. The 1 < z < 2 passive galaxies in our sample have central mass densities that are several times larger than seen in early-type galaxies today, but quite comparable to the densities seen in compact distant red galaxies at 2 < z < 3. We use the relation between size and mass, observed both locally and at high redshifts, to remove trend with mass, and show that massive elliptical galaxies are continuously growing in size over a wide range of redshifts. I will discuss a possibility that environment may play a crucial role in assembling early-type galaxies, and consider proposed mechanisms for size evolution in contemporary models.

211.02D

A Near Infrared Spectroscopic Chronometer Suitable for JWST Confirmed with Nearby Galaxies Jesse Miner¹, J. A. Rose¹, G. Cecil¹

¹University of North Carolina - Chapel Hill. 10:20 AM - 10:40 AM

Room 607

The thermally-pulsing asymptotic giant branch (TP-AGB) dominates the near-infrared (NIR) flux of a coeval stellar population between ~0.1 and ~1 Gyr, and hence can serve as a useful chronometer. Here we present NIR spectra of the intermediate-age galaxy M32 and the post-starburst galaxy NGC~5102 with the SpeX spectrograph on the NASA Infrared Telescope Facility, and show that spectral features due to the TP-AGB and other evolutionary phases can be used to determine the mean stellar population ages of these two galaxies. Specifically, we define four NIR spectroscopic indices that measure the strength of stellar absorption features: two Paschen-series lines and two indices sensitive to carbon-rich TP-AGB stars. By comparing the observed values of these indices to those in the Maraston (2005) stellar population synthesis models for various ages and metallicities, we show that model predictions for the ages of the nuclei of M32 and NGC 5102 agree with previous results obtained from integrated optical spectroscopy and CMD analysis of the giant branches. The indices discriminate between an intermediate age population of ~3-4Gyr, a younger population of ~1 Gyr, and also detect the signatures of very young ~100 Myr populations. This technique will be useful for studying the formation history of galaxies in the early universe with the James Webb Space Telescope.

211.03D

On the Nature of Void Galaxies Kathryn Kreckel¹

¹Columbia University. 10:40 AM - 11:00 AM Room 607

On large (~10 Mpc) scales we observe that galaxies align into filaments, clusters, and walls, with large void regions between them that are (mostly) empty. Void galaxies, occupying these underdense regions, are an environmentally defined population whose isolated nature provides an ideal sample to test theories of galaxy formation and evolution. Additionally, their existence poses a well defined observational constraint to Lambda-CDM cosmological models. I will discuss my work examining the gas content and star formation history of 60 geometrically selected void galaxies in a new Void Galaxy Survey (VGS), and highlight individual void galaxies which may exhibit evidence of ongoing gas accretion.

211.04

Characterizing Clumpy Structure of z~2 Galaxies in HST Observations from CANDELS and Hydrodynamical Simulations

Mark Mozena¹, S. M. Faber², J. R. Primack¹, A. Dekel³, D. Ceverino³, D. C. Koo², M. Fumagalli¹, S. Wuyts⁴, D. J. Rosario⁴, K. Lai¹, D. D. Kocevski¹, E. J. McGrath¹, J. R. Trump¹, CANDELS

¹University of California, Santa Cruz, ²University of California Observatories/Lick Observatory, ³Racah Institute of Physics, The Hebrew University, Israel, ⁴Max-Planck-Institut fur extraterrestrische Physik (MPE), Germany.

11:00 AM - 11:10 AM

Room 607

The first data from the HST Multi-Cycle Treasury CANDELS (Cosmic Assembly Near Infra-red Deep Extragalactic Legacy Survey - candels.ucolick.org) are producing images of thousands of z~2 galaxies in observed optical (ACS) and NIR (WFC3) bands. We have developed a new visual classification scheme for

 z^2 galaxies which is motivated by the significant population of galaxies that are dominated by giant clumps in the HST images, and by the theoretical predictions for clumpy galaxies based on analytic studies and zoom-in hydrodynamical cosmological simulations. This classification method was developed using about a thousand z^2 galaxies in the GOODS-S Early Release Survey (ERS) region imaged with ACS and WFC3. The ERS data have been observed in a way similar to the CANDELS observations. I will also discuss the latest cosmologically motivated ART hydrodynamical simulations by Ceverino, Dekel, and Primack. We render these simulated z^2 galaxies to mimic our HST ACS and WFC3 images and visually classify their stellar structure to compare them with the galaxies observed in ERS. We have compared the effects of dust extinction due to the complex clumpy distribution of gas within these simulations. Comparing the visual classification of the HST observations with the simulations provides new clues to galaxy assembly.

211.05

Rest-frame Optical Imaging Of z ~ 2-3 Galaxies With HST/WFC3

David R. Law¹, C. C. Steidel², A. E. Shapley¹, S. R. Nagy¹ ¹UCLA, ²Caltech. 11:10 AM - 11:20 AM *Room 607*

I will describe some early results from an ongoing HST/WFC3 rest-frame optical imaging survey of starforming galaxies in the redshift range 1.5 < z < 3.5. With 42 orbits of F160W imaging distributed amongst 10 survey fields, our survey will cover 65 square arcmin to a depth of 27.9 AB and contain > 300 spectroscopically confirmed galaxies with stellar masses in the range M* = 1e9 - 1e11 solar masses. I will discuss the typical morphological properties of these galaxies, the relation between morphology and the strength of galactic-scale gaseous outflows, and the form of the mass-radius relation in comparison to local galaxy samples.

211.06

Insights Into Galaxy Evolution From Photometric Redshifts Across Many Fields Ralf Kotulla¹

¹University of Wisconsin - Milwaukee.

11:20 AM - 11:30 AM

Room 607

I present results from a compiled sample spanning a range of public deep-fields, including the GOODS, COSMOS, UKIDSS-UDS and MUSYC fields. Photometric redshifts for these fields were obtained using a homogenous approach using the GAZELLE photo-z code; stellar masses and star formation rates have been estimated by comparison to GALEV evolutionary synthesis models, spanning a wide range of galaxy evolution scenarios.

The derived redshift distributions show generally good agreement with predictions from semi-analytical models, based on simulations of cosmological structure formation. Mass-functions of these fields reveal a population of very massive, yet actively star-forming galaxies, in numbers exceeding predictions of current semi-analytical models and hence hinting at an as yet insufficiently understood formation channel producing this kind of galaxy.

212 *AGN, QSO, Blazars III* Oral Session *Room 609*

212.01

Multiwavelength Spectral Studies Of Fermi-LAT Blazars

Manasvita Joshi¹, A. Marscher¹, S. Jorstad¹, I. Agudo¹, V. Larionov², M. Aller³, M. Gurwell⁴, A. Lähteenmäki⁵

¹Boston University, ²St. Petersburg State University, Russian Federation, ³University of Michigan, ⁴SAO, ⁵Metsähovi Radio Obs, Finland.

10:00 AM - 10:10 AM

Room 609

We present multiwavelength spectral analyses of several Fermi-LAT selected blazars that are part of the Boston University multiwaveband polarization monitoring program. The data for the objects of this study have been compiled from observations with Fermi, RXTE, the VLBA, and various ground-based optical telescopes starting in August 2008. We simulate the dynamic spectral energy distributions (SEDs) within the framework of a multi-zone time-dependent leptonic jet model

for blazars, with radiation feedback, in the internal shock scenario. We discuss the intrinsic parameter differences present between the various blazar subclasses of our sample set and the interplay between synchrotron and inverse Compton radiation processes

responsible for producing the resultant SEDs.

This research was supported in part by NASA through Fermi grants NNX10AO59G, NNX08AV65G, and NNX08AV61G and ADP grant NNX08AJ64G, and by NSF grant AST-0907893.

212.02D

Are Jets Monoparametric? Extending the Blazar Sequence to the Blazar Envelope in the Fermi Era Eileen T. Meyer¹, G. Fossati¹, M. Georganopoulos², M. Lister³

¹*Rice University*, ²*University of Maryland, Baltimore County*, ³*Purdue.*

10:10 AM - 10:30 AM

Room 609

The blazar sequence, first discovered by Fossati et al. (1998), unified the broad emission line, highpowered flat spectrum radio quasars (FSRQ) with the optically featureless BL Lac objects through a simple anti-correlation between synchrotron peak luminosity and peak frequency. This paradigm has come under scrutiny as increasing numbers of sources have emerged off the sequence. We have found evidence for a simple underlying scheme for the apparent 'blazar envelope': blazar jets are monoparametric engines, such that source power (as measured from the low-frequency, un-beamed extended emission) creates a monotonic relationship between the intrinsic peak luminosity and peak frequency of the synchrotron and inverse Compton components. The envelope naturally emerges below the sequence due to the drop in peak luminosity and frequency as sources are progressively aligned away from our line-of-sight and relativistic beaming drops. We present key evidence for this scheme which has impact on theoretical models of blazar jets with velocity profiles. The envelope also allows us to more clearly unify blazars and the parent population of FR I and II radio galaxies. I will discuss some of the difficulties and caveats in measuring the source power through extended emission, current results, and future applications of this simple idea to broader unification schemes and other source classes.

212.03

Time-dependent Radiative Transfer In Blazar Jets: Combining Monte-Carlo Shock Acceleration Simulations With Radiative Transfer.

Omar Jamil¹, M. Boettcher¹, M. Baring²

¹Ohio University, ²Rice University.

10:30 AM - 10:40 AM

Room 609

We present the first results from time-dependent blazar jet radiation transfer simulations. Monte-Carlo simulations for relativistic shock acceleration have been conducted to solve for representative electron spectra injected in the jet shock environs; these are used as an input into our radiation transfer code. Our code can handle arbitrary electron distributions on arbitrary spatial grids, as resulting from the shock acceleration simulations. It evaluates self-consistently the synchrotron and synchrotron self-Compton emission, particularly relevant for high-frequency- peaked BL Lac objects. With our new code, we are able to study in detail spectral variability patterns in blazar spectra and their relation to the underlying electron acceleration and cooling mechanisms. This offers the potential for new insights into shock MHD conditions and embedded turbulence in blazars. In addition, our simulations can also be applied to analyze the jet timing properties in other astrophysical systems such as X-ray binaries.

212.04

Radiative Transfer and Radiative Driving of Outflows in AGN and Starbursts

Gregory Novak¹, J. P. Ostriker¹, L. Ciotti²

¹Princeton University, ²University of Bologna, Italy.

10:40 AM - 10:50 AM

Room 609

We have performed axisymmetric hydrodynamic simulations of an isolated L+ elliptical galaxy including accretion by the central black hole, star formation, and feedback due to both processes. The effects of the central black hole on the temperature and momentum of galactic gas resulting from both radiative and mechanical feedback (in the form of a broad-line wind) are treated carefully using a detailed and physically well-motivated prescription. The simulations cover a range of length scales from ~1 pc to ~100 kpc, ensuring that gas that leaves the simulation via the inner edge and accretes onto the black hole has thermal energy less than its kinetic energy (that is, the Bondi radius is resolved even for the hot gas in the system). We carefully treat the forces on the gas due to dust opacity in the UV, optical, and IR bands from photons generated by both stars and the central AGN. The effects of star formation, Type II supernovae, Type Ia supernovae, mass injection by planetary nebulae, dust destruction by sputtering, and radiative forces due to Compton scattering and photoionization opacity are all taken into account. We find that radiative feedback is important, but the effect of the broad-line wind is dominant. We also find that the black hole accretion rate depends strongly on the inner radius of the simulation, implying that physical processes that operate on infalling gas between 1 and 100 pc have an important effect on the true black hole accretion rate.

212.05D

Very-High-Energy Gamma-Ray Induced Pair Cascades in Blazars and Radio Galaxies Parisa Roustazadeh¹, M. Boettcher¹

¹Ohio University. 10:50 AM - 11:10 AM *Room 609* Recent blazar detections by H.E.S.S., MAGIC, and VERITAS suggest that very-high-energy (VHE, E > 100 GeV) gamma-ray production may be common to most radio-loud Active Galactic Nuclei (AGN). We have investigated the signatures of Compton-supported pair cascades initiated by VHE gamma-ray absorption in arbitrary radiation fields, including monochromatic Ly-alpha line emission from the Broad Line Region and thermal infrared radiation from a circum-nuclear dust torus. We follow the spatial development of the cascade in full 3-dimensional geometry. We show that even for relatively weak magnetic fields, the cascades can be efficiently isotropized, leading to substantial off-axis cascade emission peaking in the Fermi energy range at detectable levels for nearby radio galaxies. We provide model fits to the gammaray loud radio galaxies NGC 1275 and Cen A, demonstrating that off-axis cascade emission may play an important role for the gamma-ray emission from radio galaxies observed by Fermi. This work was supported by NASA through Fermi Guest Investigator Grants NNX09AT81G and NNX10AO49G.

212.06

How To Use The Cubic Tev Variability Of PKS 2155-304 As A Jet Speedometer. Markos Georganopoulos¹

¹UMBC.

11:10 AM - 11:20 AM

Room 609

Recently, Aharonian et al. reported TeV variability in the blazar PKS 2155-304 that scaled with the cube of the synchrotron variability. As I will discuss, this cubic behavior that challenges the common scenarios for the TeV-blazar emission can be explained if the Lorentz factor of the emitting plasma is significantly higher than usually presumed.

212.07

Correlations of Quasar Optical Spectra with Radio Morphology

Amy E. Kimball¹, Z. Ivezic², P. J. Wiita³, D. P. Schneider⁴

¹NRAO, ²University of Washington, ³College of New Jersey, ⁴Pennsylvania State University.

11:20 AM - 11:30 AM

Room 609

Using a large sample of radio quasars with high-quality optical spectra, we have investigated statistical relationships between some important radio and optical properties of quasars. Our sample consists of 4714 radio quasars from FIRST and SDSS, classified by eye into several radio morphology classes, including classical triples, doubles, and unresolved sources. We examine optical colors of these subsamples and find that radio quasars unresolved by FIRST have a redder color distribution than radio-quiet quasars; other classes of radio quasars have color distributions similar to the radio-quiet quasars. We use two supposed statistical indicators of quasar orientation, the radio core-to-lobe ratio (R) and the core radio-to-optical ratio (R₁), to explore correlations of several optical spectral line parameters with orientation, and as a function of radio morphology. It appears that R₁ is a better orientation indicator than R. An important result of this study is that optical line equivalent widths (EWs) tend to increase with both R and R₁, suggesting that, in contrast to commonly accepted orientation-based theories, quasar EWs increase as the line-of-sight angle to the radio-jet axis decreases.

This material is based upon work supported under a National Science Foundation Graduate Research Fellowship, and by NSF grant AST-0507259 to the University of Washington. D.P.S. acknowledges support from NSF grant AST-0607634.

213 *Galaxy Clusters: Surveys and AGN* Oral Session *Room 604*

213.01

Growth of Structure Measurement from a Large Cluster Survey using Chandra and XMM-Newton John R. Peterson¹, J. G. Jernigan², R. Gupta³, J. Bankert¹, S. M. Kahn⁴, M. Sako⁵, T. Krane⁵, A. Lawrence⁶ ¹Purdue University, ²UC Berkeley, ³U. Pennsylvania, ⁴SLAC/Stanford, ⁵U Pennsylvania, ⁶U Edinburgh, United Kingdom.

10:00 AM - 10:10 AM

Room 604

We present a large X-ray selected serendipitous cluster survey based on a novel joint analysis of archival Chandra and XMM-Newton data. The survey provides enough depth to reach clusters of flux of $\sim 10^{-14}$ ergs cm⁻² s⁻¹ near z \sim 1 and simultaneously a large enough sample to find evidence for the strong evolution of clusters expected from structure formation theory. We detected a total of 723 clusters of which 462 are newly discovered clusters with greater than 6 significance. In addition, we also detect and measure 261 previously-known clusters and groups that can be used to calibrate the survey. The survey exploits a technique which combines the exquisite Chandra imaging quality with the high throughput of the XMM Newton telescopes using overlapping survey regions. A large fraction of the contamination from AGN point sources is mitigated by using this technique. This results in a higher sensitivity for finding clusters of galaxies with relatively few photons and a large part of our survey has a flux sensitivity between 10⁻¹⁴ and 10⁻¹⁵ ergs cm2 s-1. The survey covers 41.2 square degrees of overlapping Chandra and XMM Newton fields and 122.2 square degrees of non-overlapping Chandra data. We measure the log N-log S distribution and fit it with a redshift-dependent model characterized by a luminosity distribution proportional to $e^{-z/20}$. We find that z0 to be in the range 0.7 to 1.3, indicative of rapid cluster evolution, as expected for cosmic structure formation using parameters appropriate to the concordance cosmological model. With a combination of SDSS, UKIDSS, and pointed optical follow-

the concordance cosmological model. With a combination of SDSS, UKIDSS, and pointed optical followup observations, we are measuring the false detection rate and estimating photometric redshifts. This will enable precision measurements of cosmological parameters by using the evolution of the cluster mass function.

213.02D

Characterizing the First Large Sample of Strong Lensing Selected Galaxy Clusters Matthew Bayliss¹, M. D. Gladders¹, J. F. Hennawi², K. Sharon¹, B. P. Koester¹ ¹University of Chicago, ²Max Plank Institute for Astronomy, Germany.

10:10 AM - 10:30 AM

Room 604

Strong lensing by galaxy clusters is a phenomenon that touches on a variety of areas in astrophysics and cosmology. Strong lensing probes the detailed matter distribution in the cores of the lensing clusters, which informs studies of the structure and formation histories of clusters. The ensemble statistics of cluster-scale strong lensing also provide a powerful test for cosmological and large-scale structure models in a way that complements studies of the evolution of structure that rely on counting clusters as a function of mass and redshift. Additionally, cluster lenses serve as natural telescopes and magnify the distant universe behind them. In spite of their great promise galaxy cluster lenses are extraordinarily rare, and this fact has historically limited their usefulness. In order to overcome the limitations imposed by the small and heterogeneously selected samples of strong lensing clusters available for study, we have systematically searched two large optical imaging survey - the Sloan Digital Sky Survey (SDSS) and

the Red-Sequence Cluster Survey 2 (RCS2) for galaxy clusters which distort background galaxies into Giant Arcs via strong gravitational lensing. In each survey we identify hundreds of high-confidence cluster lens candidates, with an aggregate sample of approximately 200 well-selected systems having giant arcs with average separations of at least ~5 arcseconds from the BCG/core of the foreground cluster lens. I will discuss the methods used to identify this unprecedented new lens sample, as well as the results of the initial stages of follow-up imaging and spectroscopy aimed at characterizing the properties of the sample - both the foreground cluster lenses as well as the background lensed sources

213.03D

Growth of Magnetic Fields in Clusters of Galaxies via Feedback-regulated AGN Outflows

Paul M. Sutter¹, P. M. Ricker¹, H. Yang¹, Illinois Cosmological Simulation Group ¹University of Illinois at Urbana-Champaign.

10:30 AM - 10:50 AM

Room 604

Feedback processes associated with active galactic nuclei (AGN) found at the centers of clusters of galaxies are a possible source for weak cluster-wide magnetic fields. However, the scales and physics involved in studying these processes necessitate the use of subgrid techniques. We present large-scale simulations of clusters using the 3D adaptive mesh refinement MHD solver in FLASH. We couple this solver to a subgrid model of the accretion onto AGN and the subsequent injection of kinetic, thermal, and magnetic energy. We employ a newly-developed fast and highly parallel halo finder to track the evolution of AGN in a cosmological volume. We study a variety of plausible subgrid models and discuss their impact on accretion rates and cluster magnetic properties.

213.04D

A Multi-Wavelength Study of AGN and Star Formation in Galaxy Clusters

David Wesley Atlee¹, P. Martini¹

¹The Ohio State University. 10:50 AM - 11:10 AM

Room 604

Room 604

Clusters of galaxies have long been used as laboratories for the study of galaxy evolution because the processes that impact morphology and star-formation rates (SFRs) in dense environments occur most rapidly in clusters. We present results from a study of AGN and star-formation in 8 low-redshift galaxy clusters. We construct spectral energy distributions (SEDs) from visible and MIR observations of cluster galaxies and fit model SEDs to the observed fluxes. These fits measure stellar masses and SFRs of the cluster members, which we use to predict the X-ray luminosity of each cluster member. X-ray luminosities in excess of the predictions indicate the presence of an AGN. AGN can also be identified from their model SEDs. The AGN selected by these two techniques are largely disjoint: only 8 out of 44 AGN are identified in X-rays and from their model SEDs. We find a positive correlation between SFR and radius within the host cluster, consistent with the SFR--density relation, but there is no apparent correlation between radius and accretion rate. However, the relationship between AGN accretion and host star-formation in cluster AGN hosts does not significantly differ from the relationship shown by $z \approx 0.8$ field AGNs and their hosts. Since SFR correlates with radius, field galaxies at z=0 must have larger SFRs relative to their black hole growth than field galaxies at $z \approx 0.8$. This is consistent with evolution in the M_{BH} - M_{bulge} relation. We also measure the fractions of cluster members with star-formation and AGN to determine the AGN duty cycle in star-forming galaxies. At time of writing, results are pending. I am grateful to The Ohio State University and the Spitzer grant program for supporting this work.

213.05

The Buildup of Passive Galaxies in Clusters and the Field Over the Last 7 Billion Years. Gregory Rudnick¹, A. van der Wel², J. Moustakas³, P. Jablonka⁴

¹University of Kansas, ²Max-Planck-Institute for Astronomy, Germany, ³University of California, San Diego, ⁴EPFL, Ecole Polytechnique de Lausanne, Switzerland.

11:10 AM - 11:20 AM

Room 604

One of galaxy evolution's most long-standing problems is determining how clusters affect the properties of infalling galaxies. One useful metric for this is how quickly the passive galaxy population in clusters assembles over time. Standard practice has been to assume that all red sequence galaxies are passive and to measure the evolution in the red fraction and red sequence luminosity function over time. This approach, however, neglects the possible contribution of dusty galaxies to the red sequence, which can be significant at intermediate environment and low to intermediate stellar masses. We move beyond a simple red sequence cut by using a new multi-color technique to distinguish red passive galaxies from red dusty star-forming galaxies. Isolating passive galaxies is inherently more physical than studying galaxies selected on one color alone. We track the buildup of passive galaxies in the field and in clusters using the COSMOS data for the former and a large imaging and spectroscopy survey of intermediate redshift clusters for the latter. The fraction of passive galaxies in clusters increases with increasing galaxy mass, increasing cluster velocity dispersion, and with time at a fixed mass and velocity dispersion. We relate the passive fraction in clusters to that for field galaxies of similar masses and use this to constrain the processes that shut off star formation in infalling cluster galaxies. The fraction of dust-obscured star forming galaxies changes with stellar mass and environment and this affects the interpretation of the rapid evolution in the faint red sequence galaxy population and its environmental dependence, as seen in other works.

213.06

A GMBCG Galaxy Cluster Catalog of 55,437 Rich Clusters from SDSS DR7

Jiangang Hao¹, T. Mckay², B. Koester³, E. Rykoff⁴, E. Rozo³, J. Annis¹, R. H. Wechsler⁵, A. Evrard², S. Siegel², M. Becker³, M. Busha⁵, D. Gerdes², D. Johnston¹, E. Sheldon⁶

¹Fermi National Accelerator Laboratory, ²The University of Michigan, ³University of Chicago, ⁴Lawrence Berkeley National Laboratory, ⁵Stanford University, ⁶Brookhaven National Laboratory. 11:20 AM - 11:30 AM

Room 604

We present a large catalog of optically selected galaxy clusters from the application of a new Gaussian Mixture Brightest Cluster Galaxy (GMBCG) algorithm to SDSS Data Release 7 data. The algorithm detects clusters by identifying the red sequence plus Brightest Cluster Galaxy (BCG) feature, which is unique for galaxy clusters and does not exist among field galaxies. Red sequence clustering in color space is detected using an Error Corrected Gaussian Mixture Model. We run GMBCG on 8240 square degrees of photometric data from SDSS DR7 to assemble the largest ever optical galaxy cluster catalog, consisting of over 55,000 rich clusters across the redshift range from 0.1 < z < 0.55. We present Monte Carlo tests of completeness and purity and perform cross-matching with X-ray clusters and with the maxBCG sample at low redshift. These tests indicate high completeness and purity across the full redshift range for clusters with 15 or more members.

214 Cosmology I Oral Session Room 401

The Luminosity Function of Lyman-alpha Emitters at the Reionization Epoch: Observations & Theory Vithal Tilvi¹, S. Malhotra¹, J. Rhoads¹, E. Scannapieco¹, P. Hibon¹, R. Thacker², I. Iliev³, G. Mellema⁴, J. Wang⁵, S. Veilleux⁶, R. Swaters⁶, R. Probst⁷, H. Krug⁶, S. Finkelstein⁸, M. Dickinson⁷

¹Arizona State University, ²Saint Mary's University, Canada, ³University of Sussex, United Kingdom, ⁴Stockholm University, Sweden, ⁵USTC, China, ⁶University of Maryland, ⁷NOAO, ⁸Texas A&M University. 10:00 AM - 10:20 AM

Room 401

Lyman-alpha (Lya) galaxies can be observed at redshift z > 7, and offer an unique probe of cosmological reionization, since the observed number of Lya emitters depends on the degree of ionization of the intergalactic medium. In addition, Lya galaxies at high redshift are a powerful tool to study low-mass galaxy formation.

Here, we present (1) the results of a deep imaging search for z=7.7 Lya emitting galaxies using an ultra narrowband filter (filter width=9A) on the NEWFIRM imager, and (2) a physical model of Lya emitters, which is based on the idea that the Lya luminosity is proportional to the mass accretion rate rather than the total dark matter halo mass. This model can explain many observed physical properties including stellar mass, stellar age, clustering length, and luminosity functions (LF) of Lya emitters from z=3 to z=7. From our deep narrowband imaging survey, we found four candidate Lya emitters in a survey volume $^{-1.4x10^4}$ Mpc³, with a line flux brighter than $^{-18}$ erg/s/cm². If all of the candidates are real z=7.7 Lya galaxies, the observed Lya LF suggests only a modest evolution of the Lya LF from z=6.5 to z=7.7. Thus, we successfully demonstrate the feasibility of sensitive near-infrared narrowband searches using custom filters designed to avoid OH emission lines that make up most of the sky background. The spectroscopic followup of these Lya candidates is underway.

Reconstructing the Matter Power Spectrum from Lyman-Alpha

Simeon Bird¹, H. Peiris¹, M. Viel¹, L. Verde¹

¹Institute of Astronomy, Cambridge, United Kingdom.

10:20 AM - 10:30 AM

Room 401

Current analyses of the Lyman-alpha forest assume that the primordial power spectrum of density perturbations obeys a simple power law, a strong theoretical assumption which should be tested. Employing a large suite of numerical simulations which drop this assumption, we reconstruct the shape of the primordial power spectrum. Our method combines a minimally parametric framework with cross-validation, a technique used to avoid over-fitting the data. I will discuss our methods, and our results applied both to the current SDSS data and the upcoming BOSS survey.

Precision Constraints from Computational Cosmology and Type Ia Supernova Simulations

Joseph P. Bernstein¹, S. E. Kuhlmann¹, B. Norris¹, R. Biswas¹ ¹Argonne National Lab. 10:30 AM - 10:40 AM *Room 401* The evidence for dark energy represents one of the greatest

The evidence for dark energy represents one of the greatest mysteries of modern science. The research undertaken probes the implications of dark energy via analysis of large scale structure and detonationbased Type Ia supernova light curve simulations. It is presently an exciting time to be involved in cosmology because planned astronomical surveys will effectively result in dark sector probes becoming systematics-limited, making numerical simulations crucial to the formulation of precision constraints. This work aims to assist in reaching the community goal of 1% constraints on the dark energy equation of state parameter. Reaching this goal will require 1) hydrodynamic+N-body simulations with a minimum of a 1 Gpc box size, 2048³ hydrodynamic cells, and 10¹¹ dark matter particles, which push the limits of existing codes, and 2) a better understanding of the explosion mechanism(s) for Type Ia supernovae, together with larger, high-quality data sets from present and upcoming supernova surveys. Initial results are discussed from two projects. The first is computational cosmology studies aimed at enabling the large simulations discussed above. The second is radiative transfer calculations drawn from Type Ia supernova explosion simulations aimed at bridging the gap between simulated light curves and those observed from, e.g., the Sloan Digital Sky Survey II and, eventually, the Dark Energy Survey.

The Un-observed Universe: Observations Rahul Biswas¹

¹Argonne National Laboratory. 10:40 AM - 11:00 AM Room 401

The standard model of cosmology, Λ CDM is a minimal model consistent with all currently available cosmological data. Consequently, studying deviations from the observable predictions of this model to constrain possible extensions to this minimal model is a prime objective of current cosmological efforts. Accordingly, detailed surveys are being conducted and planned to elucidate the properties of the directly unobserved "dark" components by studying their gravitational effects using well known techniques involving Type Ia supernovae, gravitational lensing or the distribution of galaxies and galaxy clusters. Similarly, the physics of the early universe and the primordial fluctuations is also being probed by extremely sensitive CMB studies.

Despite the unprecedented precision levels of these surveys, the objectives are extremely challenging due to inherent uncertainties in the procedure as well as numerous possible extensions to the minimal model. Therefore, it is desirable to use the data to constrain extensions in more ways in addition to the well established techniques. We offer novel methods of additionally utilizing large scale structure data or CMB data to address this challenge.

A New Method For Cosmological Parameter Estimation From SNIa Data

Marisa March¹, R. Trotta¹, P. Berkes², G. D. Starkman³, P. M. Vaudrevange³ ¹Imperial College London, United Kingdom, ²Brandeis University, ³Case Western Reserve University. 11:00 AM - 11:10 AM

Room 401

We present a new methodology to extract constraints on cosmological parameters from SNIa data obtained with the SALT2 lightcurve fitter. The power of our Bayesian method lies in its full exploitation of relevant prior information, which is ignored by the usual chisquare approach. Using realistic simulated data sets we demonstrate that our method outperforms the usual chisquare approach 2/3 of the time while achieving better long-term coverage properties. A further benefit of our methodology is its ability to produce a posterior probability distribution for the intrinsic dispersion of SNe. This feature can also be used to detect hidden systematics in the data.

Using Luminous Red Galaxies as Cosmic Chronometers

Steven M. Crawford¹, S. Blyth², C. Cress³, E. A. Olivier¹, A. L. Ratsimbazafy³, K. van der Heyden² ¹South African Astronomical Observatory, South Africa, ²University of Cape Town, South Africa, ³University of the Western Cape, South Africa. 11:10 AM - 11:20 AM

Room 401

We highlight some of our recent results looking at using Luminous Red Galaxies (LRGs) as cosmic chronometers. LRGs provide a potentially promising method for measuring the cosmic expansion of the Universe by accurately age dating these passively evolving galaxies. However, the measurement of H(z) is limited by the accuracy and precision in the ages of the LRGs. In our recent work, we quantify the uncertainties on the measurement of H(z) by examining LRG populations in numerical simulations. From the simulated star formation histories for LRGs, we find that single stellar populations can not provide the accuracy required to measure H(z) at intermediate redshifts. However, we find that we are able to recover H(z) to within 3 per cent at $z^{-0.42}$ by: (1) age dating the LRGs using extended star formation histories that realistically replicate those predicted in the simulations, and (2) selecting a homogeneous sample of LRGs that are not affected by late bursts of star formation. We present a observing program optimized for the Southern African Large Telescope to perform such a measurement. Finally, we present some initial results on age dating LRGs from existing surveys along with a comparison of different techniques to determine the ages. This work was supported by the National Research Foundation of South Africa.

Halos and Galaxies in the Cosmic Web from Numerical Simulations Darren S. Reed $^{\rm 1}$

¹Univ. of Zurich, Switzerland. 11:20 AM - 11:30 AM Room 401

We use cosmological simulations to explore the distribution of low mass halos and galaxies within the cosmic web of dark matter. There has been significant focus on the apparent fact that low mass dwarf galaxies are ``missing'' with respect to the numbers of low mass halos in the concordance Lambda Cold Dark Matter (CDM) cosmology. The ``missing'' CDM halos may be present, but dark, or instead, we could live in a warm dark matter universe where low mass halo formation is suppressed. We explore whether the spatial distribution of galaxies in voids and filaments can discriminate between the above astrophysical or cosmological solutions, and what it can reveal about about the relation between galaxy luminosity and halo mass.

215 *Pulsars, Neutron Stars I* Oral Session *Room 4C-1*

215.01

Progress Report on a New Survey of Unidentified Radio Sources for Fast Pulses and Bursts Fronefield Crawford¹, G. Langston², D. Schmidt¹, C. Gilpin¹

¹Franklin & Marshall College, ²National Radio Astronomy Observatory.

10:00 AM - 10:10 AM

Room 4C-1

A sample of 92 unidentified, highly polarized radio sources from the FIRST and NVSS radio surveys is being surveyed for very fast (possibly sub-millisecond) pulses and bursts. This is the same sample that was previously searched for pulsars by Crawford, Kaspi, & amp; Bell (2000), but this new survey uses a much wider bandwidth, leading to a better discrimination between interference and dispersed radio signals while also reducing the likelihood of missing pulsars due to scintillation. A repeated search of these same sources at a different observing epoch is also justified given that emission from compact objects has been observed to be highly time-variable in some cases (e.g., transients, nullers, eclipsing

binaries). We report on the progress of this survey, which is being conducted by undergraduate students at Franklin and Marshall College.

215.02

First Detection of Gamma-ray Pulsations from a Globular Cluster Millisecond Pulsar with the Fermi Large Area Telescope

Damien Parent¹ ¹NRL / GMU. 10:10 AM - 10:20 AM Room 4C-1

Millisecond pulsars (MSPs) have recently been confirmed by the Fermi Large Area Telescope as a class of pulsed gamma-ray emitters. They have been observed individually contributing to the population of high latitude gamma-ray sources, and suggested to explain the gamma-ray emission of globular clusters as a collective emission. We will present the first detection of gamma-ray pulsations from a globular cluster MSP, PSR J1823-3021A in NGC 6624. The pulsar has an unusually large period derivative and is one of the most energetic MSPs detected in gamma-rays (spin-down luminosity of 8E35 erg/s). It is located 7.9 kpc away in the core of the cluster, which includes three other MSPs, two normal pulsars, and the bright X-ray source 4U 1823-30. We will present the environment and pulsed gamma-ray emission which appears to be aligned with radio peaks, a phenomenon only seen in 3 MSP to date.

215.03D

A Study of Globular Cluster Pulsars Using the Green Bank Telescope **Ryan Lynch**¹

¹UVA.

10:20 AM - 10:40 AM

Room 4C-1

The Green Bank Telescope has been used to find 68 pulsars in 13 globular clusters, the majority of them being millisecond pulsars. I report on the latest round of GBT cluster searches. Twenty clusters have been searched, some for the first time, and all more sensitively than ever before, and eight new pulsars have been discovered in M22, M28, NGC 5986, and NGC 6517. Seven of the new pulsars are true MSPs with spin periods &It; 10 ms, and three of the pulsars are in binary systems. I also report on seven new timing solutions for previously known pulsars in M62, NGC 6544, and NGC 6624. Some highlights include a long-period, mildly eccentric binary and potential new double neutron star system. Many of the new pulsars can be used to place limits on the mass-to-light ratio deep in the cluster cores. Motivated by an isolated MSP in NGC 6517 that lies nearly 20 core radii from the cluster center, I have developed a new probability analysis for globular cluster pulsar positions, which I apply to those pulsars with well measured positions. Finally, I present a study of the population of non-recycled pulsars originating in globular clusters.

215.04D

Modeling and Maximum Likelihood Fitting of Millisecond Pulsar Gamma-ray and Radio Lightcurves Tyrel J. Johnson¹, C. Venter², A. K. Harding³

¹Univ. of Maryland, ²North-West University, South Africa, ³NASA Goddard Space Flight Center. 10:40 AM - 11:00 AM

Room 4C-1

The Large Area Telescope on-board the Fermi Gamma-ray Space Telescope has detected significant pulsations from many known millisecond pulsars, helped discover new radio millisecond pulsars, and detected significant gamma-ray emission from the vicinity of eight globular clusters which display the characteristic pulsar gamma-ray spectrum. These discoveries suggest that gamma-ray emission from

millisecond pulsars must be the rule and not the exception. We have produced radio and gamma-ray light curve simulations, assuming a retarded vacuum-dipole magnetic field geometry, for several geometric gamma-ray emission models and a radio cone beam model, and developed a Markov chain Monte Carlo maximum likelihood fitting technique to compare with the observations. This technique produces confidence contours in pulsar viewing geometry space which can be directly compared with those from radio polarization measurements. These results can provide a basis for studying the emission properties of population models used to simulate the combined emission of many millisecond pulsars as observed in globular clusters, as well as the probable contributions to the Galactic and isotropic diffuse gamma-ray emissions.

215.05

Measurements Of Masses And Radii Of Neutron Stars Using Thermonuclear X-ray Bursts. Tolga Guver¹, F. Ozel¹

¹The University of Arizona.

11:00 AM - 11:10 AM

Room 4C-1

Low mass X-ray binaries that show thermonuclear X-ray bursts are excellent targets for constraining the equation of state of neutron star matter. We make use of time resolved, high count rate X-ray spectra to measure the Eddington limit and the apparent radii of neutron stars. I will discuss how these spectroscopic observations have enabled the measurement of the masses and radii of the neutron stars in several low mass X-ray binaries. I will also show how these measurements led to the first significant constraints on the equation of state of the neutron star matter.

215.06D

Hydrodynamics and Radiation Transport in Radiation Dominated Accretion onto Neutron Stars Kenneth D. Wolfram¹, P. A. Becker²

¹Naval Research Laboratory, ²George Mason University.

11:10 AM - 11:30 AM

Room 4C-1

The problem of spectral formation in accretion-powered X-ray pulsars was solved for the first time using an analytical model based on the fundamental physics in 2007, and the resulting spectra were shown to agree rather closely with those observed from several of the most luminous sources. However, in order to derive the analytical solutions, simplifying assumptions were made regarding the inflow velocity profile, the thermal structure of the plasma, the boundary conditions, and the geometry of the column. In this paper, the problem is revisited using a new numerical approach that facilitates the solution of a more realistic, coupled radiative-hydrodynamical model. The new model utilizes a conical geometry for the accretion flow and applies a robust free-streaming boundary condition at the top of the column, along with a "mirror" boundary condition at the neutron star surface. The temperature of the electrons is computed based on inverse-Compton equilibration, and the hydrodynamical structure of the column is determined by solving the coupled set of conservation equations for momentum, energy, and mass. The column-integrated spectra computed using the new model are compared with the data for several sources, and the resulting source parameters are compared with those computed using the original analytical model.

216 *Interstellar Medium: Molecular Gas* Oral Session *Room 4C-3*

216.01

Midplane Pressure and the Abundance of Molecular Hydrogen in Galaxies: Insights from Non-Equilibrium Chemical Models

Mordecai-Mark Mac Low¹, S. C. O. Glover²

¹American Museum of Natural History, ²Institut für Theoretische Astrophysik, Zentrum für Astronomie der Universität Heidelberg, Germany.

10:00 AM - 10:10 AM

Room 4C-3

Observations of spiral galaxies show a strong linear correlation between midplane pressure and the ratio of molecular to atomic hydrogen surface density R. The suggestion has been made that this occurs because of the equilibrium balance between radiative dissociation of molecular hydrogen and formation on the surfaces of dust grains. We use a 3D numerical model of magnetized turbulence including a simplified chemical network and treatment of the propagation of dissociating radiation to examine this question. We find that the formation timescale for molecular hydrogen is sufficiently long that equilibrium is not reached within the lifetimes of molecular clouds of 20-30 Myr. However, if we assume that the effective temperature in galactic disks is roughly constant, the correlation of R with pressure corresponds to a correlation with local gas density. We find that if we examine the value of R in our local (5-20 pc box) models after a free-fall time at the average density, the observational ratio is reproduced well over two orders of magnitude in density. This supports the suggestion that the formation of molecular clouds and of stars in galaxies proceeds from large-scale gravitational instability, and so that the observed linear correlation between the star formation rate and molecular hydrogen surface densities occurs because both have a common cause.

216.02D

Molecular Hydrogen in Cosmological Simulations of Galaxies

Charlotte Christensen¹, T. Quinn¹, F. Governato¹

¹University of Washington.

10:10 AM - 10:30 AM

Room 4C-3

The near-constant star formation efficiency observed in molecular clouds indicates that star formation in galaxies is regulated by the transition from atomic to molecular gas. Simulations enable us to follow this transition and its relationship to external processes, even in low-metallicity galaxies where H₂ is difficult to observe. I have extended the SPH+N-body code, Gasoline, to calculate the non-equilibrium abundances of H₂. These abundances are based on the local rates of formation and destruction, such as dust grain formation and dissociation from Lyman-Werner flux, as modulated by dust and self-shielding. The H₂ in turn both acts as an additional source of cooling and is used when determining star formation (SF). With this code, I have integrated several high-resolution, cosmological simulations of low-mass galaxies to redshift zero, including a dwarf galaxy with both a realistic rotation curve and bulge-to-disk ratio. Here I present results from analyzing the relation between H₂ and SF in these galaxies. In particular, I show that the inclusion of H₂ in simulations of low mass galaxies, results in more extended star formation histories and stellar distributions. I further analyze the transformation of the Kennicutt-Schmidt law when it is determined at galaxy-wide to 100 pc scales. Finally, I relate the local abundance

of H₂ large-scale processes, including mergers, spiral structure, and gas in-fall. Ths research was supported by the National Science Foundation.

216.03D

Simulations of Massive Star Cluster Formation and Feedback in Turbulent Giant Molecular Clouds Elizabeth Harper-Clark¹, N. Murray¹

¹University of Toronto, Canada.

10:30 AM - 10:50 AM

Room 4C-3

Using the AMR code ENZO I am simulating the formation of individual stars into massive star clusters within turbulent Giant Molecular Clouds (GMCs). I will address how initial conditions affect the star formation and how energy and momentum from a massive star cluster can disrupt a GMC - even before supernovae. I will talk about the simulations from the first stages of building realistic turbulent GMCs, to accurate star formation and, finally, feedbacks. These simulations aim to build a better understanding of how stars affect the GMCs they are born within, helping to answer the questions of how long GMCs live and why only a small fraction of GMC gas makes it in to stars.

216.04D

The Properties and Formation of Infrared Dark Clouds

Audra K. Hernandez¹, J. C. Tan¹

¹Univ. of Florida.

10:50 AM - 11:10 AM

Room 4C-3

Stars are born within and from the densest regions of Giant Molecular Clouds (GMCs). When seen in absorption against the diffuse mid-infrared Galactic background, these regions are known as Infrared Dark Clouds (IRDCs) and are likely to be at an early evolutionary stage in the star formation process, thus yielding information on the initial conditions of massive star and star cluster formation. I present two studies using CO line emission to gain insight on the physical properties and formation of IRDCs and their surrounding GMCs. First, for one highly filamentary IRDC, I compare mass surface densities derived from CO emission, observed with the IRAM 30m telescope, with those derived using mid-IR extinction mapping. I find agreement between the two methods at the factor of two level, over a range of mass surface densities of 0.01 to 0.09 g/cm². As surface densities increase, there is a trend for the CO derived estimates to decrease relative to mid-IR extinction mapping, which may indicate effects of depletion or systematic temperature gradients. Ellipsoidal and filamentary virial analyses suggest that surface pressure terms are dynamically important and that the IRDC may not yet have reached virial equilibrium. Second, using a large sample of IRDCs, I analyze the properties of their surrounding GMCs traced by 13CO from the Galactic Ring Survey of Jackson et al., especially their rotation and degree of virialization. A substantial fraction of the clouds rotate in a retrograde sense compared to their Galactic orbits, supporting models of IRDC formation via converging molecular flows driven by GMC collisions.

216.05

The Molecular Cloud Population of the Large Magellanic Cloud

Tony H. Wong¹, A. Hughes², MAGMA collaboration

¹University of Illinois, ²Swinburne University, Australia.

11:10 AM - 11:20 AM

Room 4C-3

With the Magellanic Mopra Assessment (MAGMA), we have recently completed a CO imaging survey of the brightest giant molecular clouds (GMCs) in the Large Magellanic Cloud (LMC). In this talk I will describe recent progress in deepening our understanding of GMC evolution using CO surveys of the

LMC. The inferred properties of LMC GMCs depend a great deal on the analysis technique, but like their Galactic cousins, they appear to be roughly in virial equilibrium and are the predominant sites for massive star formation. The velocity gradients across GMCs are similar to those found in the surrounding atomic gas and do not appear indicative of rotation. The locations of GMCs relative to young stellar objects may shed light on the contentious issue of their lifetimes; we present evidence that more massive YSOs are better associated with detectable CO emission.

216.06

The Sub-mm J=6-5 Line Of 13-CO In Orion

Thomas L. Wilson¹, D. Muders², M. Dumke³, C. Henkel², J. Kawamura⁴

¹US Naval Research Laboratory, ²Max-Planck-Inst. f. Radioastronomie, Germany, ³European Southern Observatory, Chile, ⁴Jet Propulsion Laboratory.

11:20 AM - 11:30 AM

Room 4C-3

We present a fully sampled map covering the Orion Hot Core and dense molecular ridge, in the submillimeter J=6-5 rotational transition of ¹³CO, made at 0.45 mm with an angular resolution of 13" and velocity resolution of 0.5 km s⁻¹. The map covers 3' (north-south) by 2' (east-west). The profile centered on the Hot Core peaks at 8.5 km s⁻¹, with a peak intensity of 40 K, corrected antenna temperature. This profile shows line wings extending to 30 km s⁻¹, and to -20 km s⁻¹. From a map of the intensity integrated from 0 to +18 km s⁻¹, there is a prominent maximum within 5" of the center of the Orion Hot Core. The Full Width to Half Power (FWHP) of this maximum is 37", considerably larger than regions containing complex molecules. Single dish measurements of lines from the J=2-1 or J=1-0 transitions of CO isotopes show no such distinct maximum. If the ¹³CO line is optically thin and the level populations are thermalized at 150 K, the column density for velocities between 0 to +18 km s⁻¹ is $N(^{13}CO) = 3.3 \ 10^{17} \text{ cm}^{-2}$. Using the local ¹²C to ¹³C ratio, 76, the column density of CO is N(CO)=2.6 10¹⁹ cm⁻². When combined with published dust emission data, the CO/ H_2 ratio is 9 10⁻⁶. This is more than a factor of 10 lower than the canonical value of 10⁻⁴. For the Orion South source and Orion Ridge region, the column density of CO is <25% of that found for the Hot Core but the CO/ H₂ ratios are similar. Models of Photodissociation Regions, PDR's, predict that CO lines from PDR's are only marginally optically thick. Thus the intensities of such ¹³CO lines would be below our sensitivity, so our map traces warm and dense molecular gas rather than PDR's.

217

Interstellar Medium, Cosmic Rays and Magnetic Fields Oral Session *Room 4C-4*

217.01

Classifying Structures in the ISM with Machine Learning Techniques

Christopher Beaumont¹, A. A. Goodman², J. P. Williams¹

¹Institute for Astronomy, University of Hawaii, ²Center for Astrophysics, Harvard University. 10:00 AM - 10:10 AM

Room 4C-4

The processes which govern molecular cloud evolution and star formation often sculpt structures in the ISM: filaments, pillars, shells, outflows, etc. Because of their morphological complexity, these objects are often identified manually. Manual classification has several disadvantages; the process is subjective, not easily reproducible, and does not scale well to handle increasingly large datasets. We have explored to what extent machine learning algorithms can be trained to autonomously identify specific morphological features in molecular cloud datasets. We show that the Support Vector Machine

algorithm can successfully locate filaments and outflows blended with other emission structures. When the objects of interest are morphologically distinct from the surrounding emission, this autonomous classification achieves >90% accuracy. We have developed a set of IDL-based tools to apply this technique to other datasets.

217.03D

Magnetic Fields in The Milky Way and in The Large Magellanic Clouds Revealed Through Faraday Rotation

Sui Mao¹

¹Harvard Univ.. 10:20 AM - 10:40 AM Room 4C-4

Room 4C-4

Coherent large scale magnetic fields exist in galaxies, yet their origin remains unclear. We present studies of the magnetic field structure in the Milky Way and in the Large Magellanic Cloud to shed new light on the field generation mechanism. We use the powerful Faraday rotation effect, which allows the determination of both the field direction and its strength, as the magnetic field probe. We measure the vertical magnetic field of the Milky Way toward the Galactic poles from observations of Faraday rotation toward more than 1000 polarized extragalactic radio sources at Galactic latitudes |b|>77°, using the Westerbork Radio Synthesis Telescope and the Australia Telescope Compact Array. We find median rotation measures (RMs) of 0.0 \pm 0.5 rad/m² and +6.3 \pm 0.7 rad/m² toward the north and south Galactic poles respectively, demonstrating that there is no coherent vertical magnetic field in the Milky Way at the Sun's position. If this is a global property of the Milky Way's magnetism, then the lack of symmetry across the disk rules out pure dipole or quadrupole geometries for the Milky Way magnetic field. The observed RM distribution can be explained by a disk and a halo dynamo of different parities operating simultaneously in the Galaxy. The proximity of the Large Magellanic Cloud allows a detailed study of its magnetic field structure. We have mapped the LMC's diffuse synchrotron polarization at 1.4 GHz using the Parkes Radio telescope. We present a magnetic field model of the LMC that can explain both the RMs of the diffuse polarized emission and those of the background extragalactic sources simultaneously.

217.04D

Investigating the Cosmic-Ray Ionization Rate in the Galactic ISM With ${\rm H_3}^+$ Observations Nick Indriolo 1

¹Univ. of Illinois at Urbana-Champaign.

10:40 AM - 11:00 AM

Room 4C-4

Observations of H_3^+ in the Galactic diffuse interstellar medium (ISM) have led to various surprising results, including the conclusion that the cosmic-ray ionization rate (ζ_2) is variable by over 1 order of magnitude between different diffuse cloud sight lines, with values as high as $8 \times 10^{-16} \text{ s}^{-1}$, and 3σ upper limits as low as $0.7 \times 10^{-16} \text{ s}^{-1}$. This variation is interesting, as it contradicts the typical assumption that the cosmic-ray spectrum is relatively uniform throughout the Galaxy. Instead, the flux of low-energy cosmic rays responsible for ionizing H_2 must be decreased in some regions due to particle propagation effects, and increased in other regions by local acceleration sites. Whether or not acceleration in and propagation from supernova remnants (thought to be the primary accelerators of Galactic cosmic rays) alone can account for such variability remains unknown.

I have conducted a survey of H_3^+ in diffuse clouds, which at present consists of observations toward 52 sight lines, with detections in 20 of those. In an attempt to understand variations in the inferred ionization rates, I have studied the environments through which all of these sight lines pass. I have also observed H_3^+ in 6 sight lines that probe gas in close proximity to the supernova remnant IC 443.

lonization rates inferred in 2 of these sight lines are about 20×10^{-16} s⁻¹, indicating a high flux of lowenergy particles, but the other 4 sight lines do not show absorption from H₃⁺, so the high ionization rate and particle flux seems very localized. Combining these results near a supernova remnant with those in the general ISM further enhances the variability seen in the cosmic-ray ionization rate, and requires that the concept of a uniform cosmic-ray spectrum be reviewed.

217.05

The Spectral Slope and Kolmogorov Constant of MHD Turbulence Andrey Beresnyak¹

¹Los Alamos National Laboratory.

11:00 AM - 11:10 AM

Room 4C-4

Magnetohydrodynamic turbulence is present in almost all astrophysical environments. Its properties are important for the dynamics of the intracluster medium, interstellar medium, it affects star formation rate in molecular clouds, transport properties of astrophysical fluids, etc. Recent high-resolution simulations of MHD turbulence support Kolmogorov's -5/3 spectral slope of MHD turbulence. Also, it is only recently that we were able to measure the correct value of Kolmogorov constant for MHD. If one tries to calculate, e.g., turbulent heating from the observed fluctuations using older values of the Kolmogorov constant, this estimate will be off by a factor of several. I will briefly explain why earlier simulations has not been able to capture the inertial range of MHD turbulence.

217.06

A High Metallicity High Velocity Cloud Along the Mrk 421 Sight Line

Yangsen Yao¹, J. M. Shull¹, C. W. Danforth¹

¹University of Colorado. 11:10 AM - 11:20 AM

11:10 AM - 11:

Room 4C-4

We present ultraviolet spectrocopic observations of Mrk 421 with the Cosmic Origins Spectrograph, which are further complemented by observations obtained with FUSE. A high velocity cloud (HVC) at - 130 km/s (LSR) is not visible in 21 cm emission (log $N_{HI} < 18.38$), but is detected in C II, N I, O I, O VI, Si II, Si IV, and Fe II in far ultraviolet absorption spectra. By referencing velocities to the intermediate velocity cloud at -60 km/s and jointly analyzing absorption lines of high-order H I Lyman series, we measure the H I column density in HVC as log $N_{HI} = 16.84(-0.13, +0.34)$ (1 sigma uncertainty). Comparing H I and O I, we infer the HVC metallicity to be [O/H] = 0.32(-0.39, +0.22) solar. The sight line is about 4 degrees away from the HVC complex M (specifically cloud M I). The high metallicity indicates that the HVC may represent the high velocity end of the complex and is the condensed returning gas of a Galactic fountain.

217.07

Detection Of OH+ And H2O+ Towards Orion KL

Harshal Gupta¹, P. Rimmer², J. C. Pearson¹, E. Herbst², S. Yu¹, E. A. Bergin³, HEXOS Key Program ¹Jet Propulsion Laboratory, California Institute of Technology, ²Department of Physics, Astronomy, and Chemistry, The Ohio State University, ³Department of Astronomy, University of Michigan. 11:20 AM - 11:30 AM

Room 4C-4

The reactive molecular ions, OH^+ , H_2O^+ , and H_3O^+ , key probes of the oxygen chemistry of the interstellar gas, have been observed toward Orion KL with the Heterodyne Instrument for Far Infrared on board the Herschel Space Observatory. All three N = 1 - 0 fine-structure transitions of OH^+ at 909, 971, and 1033 GHz and both fine-structure components of the doublet *ortho*- H_2O^+ 1_{11} - 0_{00} transition at 1115 and 1139

GHz were detected, and an upper limit was obtained for H_3O^+ . OH^+ and H_2O^+ are observed purely in absorption, showing a narrow component at the source velocity of 9 km s⁻¹, and a broad blue shifted absorption similar to that reported recently for HF and *para*- $H_2^{18}O$, and attributed to the low velocity outflow of Orion KL. We estimate column densities of OH^+ and H_2O^+ for the 9 km s⁻¹ component of $9 \pm 3 \times 10^{12}$ cm⁻² and $7 \pm 2 \times 10^{12}$ cm⁻², and those in the outflow of $1.9 \pm 0.7 \times 10^{13}$ cm⁻² and $1.0 \pm 0.3 \times 10^{13}$ cm⁻². Upper limits of 2.4×10^{12} cm⁻² and 8.7 ± 10^{12} cm⁻² were derived for the column densities of *ortho* and *para*- H_3O^+ from transitions near 985 and 1657 GHz. The column densities of W31C and W49N. A higher gas density, despite the assumption of a large ionization rate, may explain the comparatively low column densities of the ions. A part of this work was performed at the Jet Propulsion Laboratory, California Institute of Technology under contract with the National Aeronautics and Space Administration. Copyright 2010© California Institute of Technology. All rights reserved.

Tuesday, January 11, 2011, 11:40 AM - 12:30 PM 218 Early Astrophysics Results from Planck Invited Session Ballroom 6AB

218.01 Early Astrophysics Results from Planck Charles R. Lawrence¹

Ballroom 6AB

Since August 2009 Planck has been observing the sky at frequencies from 30 to 857 GHz, measuring not only the cosmic microwave background, but also everything else in the universe that radiates at these frequencies. I will describe the first scientific results from Planck covering a wide range of galactic and extragalactic astrophysics.

Tuesday, January 11, 2011, 2:00 PM - 3:30 PM 220 *Exoplanet Detection: Transits*

Oral Session Ballroom 6A

220.01

PTF/M-dwarfs: First Results From a Large New M-dwarf Planetary Transit Survey

Nicholas M. Law¹, A. Kraus², R. Street³, T. Lister³, A. Shporer³, L. Hillenbrand⁴, Palomar Transient Factory ¹Dunlap Institute for Astronomy and Astrophysics, University of Toronto, Canada, ²University of Hawaii, ³LCOGT, ⁴Caltech.

2:00 PM - 2:10 PM Ballroom 6A

PTF/M-dwarfs is a new 100,000-target M-dwarf planetary transit survey, a Key Project of the Palomar Transient Factory collaboration. The survey is sensitive to Jupiter-radius planets around all of the target stars, and has sufficient precision to reach Neptunes and super-Earths for brighter targets. The Palomar Transient Factory (PTF) is a fully-automated, wide-field survey aimed at a systematic exploration of the optical transient sky. The survey is performed using a new 7.26 square degree camera installed on the 48 inch Samuel Oschin telescope at Palomar Observatory; colors and light curves for detected transients are obtained with the automated Palomar 60 inch telescope. With an exposure of 60 s the survey

reaches a depth of R~20.6 (5-sigma, median seeing). Each 92-megapixel R-band exposure contains about 3,000 M-dwarfs usable for planet detection; 8-10 fields are observed in sequence in the section of PTF dedicated to 15-minute-cadence planet detection.

Every six months PTF/M-dwarfs searches for Jupiter-radius planets around almost 30,000 M-dwarfs, Neptune-radius planets around approximately 500 M-dwarfs, and super-Earths around 100 targets. The full survey is expected to cover more than 100,000 targets over the next several years. A secondary survey searching many more M-dwarfs for deeper eclipses and transits operates simultaneously throughout the year, using PTF's few-images-per night data covering 1500 square degrees of sky. Photometric and spectroscopic follow-up operations are performed on the Palomar 60-inch, Palomar 200-inch and LCOGT FTN & FTS telescopes, while Keck/HIRES provides precision radial velocity followup. The survey has been running since mid-2009 and has detected 14 new eclipsing M-dwarf binaries, as well as transiting planet candidates.

220.02D

DEMONEX: The DEdicated MONitor Of EXotransits Jason Eastman¹

¹*The Ohio State University.*

2:10 PM - 2:30 PM

Ballroom 6A

The DEdicated MONitor of EXotransits (DEMONEX) is a 0.5 meter, robotic telescope dedicated to obtaining precise photometry of bright stars with transiting planets. This photometry provides a homogeneous data set for all transits visible from its location at Winer Observatory in Sonoita, Arizona, and allows us to robustly compare planets, search for additional planets via transit timing variations (TTVs), place limits on secondary eclipses, systematically search known radial velocity planets for those that transit, and follow up promising transiting planet candidates from the Kilo-degree Extremely Little Telescope (KELT).

We describe the hardware, scheduling, observing, and data reduction software; as well as our results from the first two and half years of operation from a subset of the 250 primary transits and 150 secondary transits we have observed. We also discuss a wide-spread confusion regarding time stamps that makes stated times within the exoplanet community ambiguous at the 1-minute level, which is critical to the correct interpretation of TTVs.

220.03

Transit Monitoring of Known Exoplanets with TERMS

Stephen R. Kane¹, D. Ciardi¹, D. Fischer², D. Gelino¹, G. Henry³, A. Howard⁴, E. Jensen⁵, G. Laughlin⁴, S. Mahadevan⁶, G. Pilyavsky⁶, K. von Braun¹, J. Wright⁶

¹NASA Exoplanet Science Institute, Caltech, ²Yale University, ³Tennessee State University, ⁴University of California, ⁵Swarthmore College, ⁶Pennsylvania State University.

2:30 PM - 2:40 PM

Ballroom 6A

Transiting planet discoveries have yielded a plethora of information regarding the internal structure and atmospheres of extra-solar planets. These discoveries have been restricted to the low-periastron distance regime due to the bias inherent in the geometric transit probability. Monitoring known radial velocity planets at predicted transit times is a proven method of detecting transits, and presents an avenue through which to explore the mass-radius relationship of exoplanets in new regions of period/periastron space. Here we describe transit window calculations for known radial velocity planets, techniques for refining their transit ephemerides, and observational methods for obtaining maximum

coverage of transit windows. These methods are currently being implemented by the Transit Ephemeris Refinement and Monitoring Survey (TERMS), from which we present the latest results.

220.04

A Search for a Sub-Earth-Sized Companion to GJ 436 and a Novel Method to Calibrate Warm Spitzer IRAC Observations

Sarah Ballard¹, D. Charbonneau¹, D. Deming², H. A. Knutson³, J. L. Christiansen⁴, M. J. Holman¹, D. Fabrycky¹, S. Seager⁵, M. F. A'Hearn⁶

¹Harvard University, ²Goddard Space Flight Center, ³University of California, Berkeley, ⁴NASA Ames Research Center, ⁵Massachusetts Institute of Technology, ⁶University of Maryland.

2:40 PM - 2:50 PM

Ballroom 6A

We discovered evidence for a possible additional 0.75 R_{Earth} transiting planet in the NASA EPOXI observations of the known M dwarf exoplanetary system GJ 436. We performed a subsequent analysis of extant 8 micron observations of GJ 436 from the Spitzer Space Telescope. We found a signal of the predicted depth and at the predicted time, but this signal was dependent on the aperture used to perform the photometry. Based on these suggestive findings, we gathered new warm Spitzer observations at 4.5 microns during a time of predicted transit. The 4.5 micron data allowed us to rule out the putative planet at high confidence. We present a novel method for correcting the intrapixel sensitivity variations of the 3.6 and 4.5 micron channels of the Infrared Array Camera (IRAC) instrument on Spitzer, without which method we would not have been sensitive to the transit of a 0.75 R_{Earth} planet. Our analysis will inform similar work that will be undertaken to use warm Spitzer observations to confirm rocky planets discovered by the Kepler mission.

220.05

Results from the PTF Orion Planet Search Program

Julian C. Van Eyken¹, D. R. Ciardi¹, R. L. Akeson¹, C. A. Beichman¹, A. F. Boden², K. von Braun¹, S. R. Kane¹, P. Plavchan¹, S. V. Ramírez¹, L. M. Rebull³, J. R. Stauffer³, PTF Collaboration ¹NExScI, Caltech, ²Caltech, ³Spitzer Science Center, Caltech.

2:50 PM - 3:00 PM

Ballroom 6A

The PTF Orion project is a part of the Palomar Transient Factory (PTF), a photometric survey for astronomical transients being undertaken with a dedicated wide-field CCD array installed on the Palomar 48" telescope. The camera consists of a 12-CCD array, each 2048 by 4096 pixels, giving a total nominal 7.8 square degree field of view with 1 arcsecond pixels. The Orion project is an experiment focusing on a single pointing in the Orion star-forming region as a part of this survey. Little is known about the distribution and frequency of planets around stars that are 1-100 Myr old - the time frame in which the giant planets are expected to form. Our principal goal is to investigate the

frequency of planets around stars at these young ages. In addition, the observations provide a unique dataset to study a variety of stellar astrophysics, including eclipsing binary systems for testing star formation and evolution models; characterising stellar activity and rotational periods; and characterising previously unknown young stars in the Orion region.

40 nights of data were dedicated to the Orion project in December 2009 and January 2010 to perform intensive time-series observations with the aim of detecting close-in, Jupiter-sized planets transiting young stars. We will present some of the results from these observations.
220.06 Enabling the Ground-based Detection of Transiting Habitable-zone Earths Christopher J. Burke 1

¹*Harvard-Smithsonian Center for Astrophysics.* 3:00 PM - 3:10 PM

Ballroom 6A

The small radii and cool temperatures of M dwarfs make them favorable targets for transiting planet surveys of habitable-zone Earth and super-Earth planets. The MEarth survey has detected a super-Earth orbiting the nearby M5 star GJ 1214 and estimated the planetary mass and radius precisely. Despite this success, the MEarth survey encounters photometric noise larger than expected based upon Poisson and scintillation sources alone. I have identified precipitable water vapor (PWV) variations in the Earth's atmosphere as the likely predominant source of excess systematic noise in the MEarth survey photometry. Based upon theoretical calculations of the PWV induced noise, I show potential filter choices that eliminate PWV induced noise to a sufficient level to detect transiting Earth-sized planets from the ground around M dwarf hosts. Ciardi et al. (2010) have recently shown from Kepler data that the intrinsic variability of M dwarfs does not preclude transit detection. Thus, I am optimistic that there are no fundamental limitations to ground based detections of habitable-zone Earths for the brightest M dwarfs. The MEarth project is supported by the David and Lucile Packard Fellowship for Science and Engineering and the National Science Foundation under grant number AST-0807690.

220.07

Tilt-a-Worlds: Effects of High Rates of Obliquity Change on the Habitability of Extrasolar Planets Shawn Domagal-Goldman¹, R. Barnes², J. C. Armstrong³, J. Breiner², V. S. Meadows² ¹NASA, ²University of Washington, ³Weber State University.

3:10 PM - 3:20 PM

Ballroom 6A

We explore the impact of obliguity variations on planetary habitability in hypothetical systems with high mutual inclination. For the hypothetical systems, we restrict our exploration to systems consisting of a solar-mass star, an Earth-mass planet at 1 AU, and 1 or 2 giant planets. We verify that these systems are stable for 10⁸ years with N-body simulations. We then calculate the obliquity variations induced by the orbital architecture on the Earth-mass planets. We find that in some cases the spin axes can rotate through 360 degrees in as little as 10,000 years (John is that right? Can you look through the systems and find the most extreme case of obliquity variation?) Next, we run energy balance models (EBM) on the terrestrial planets to assess surface temperature and ice coverage on the planets' oceans. Finally, we explore differences in the outer edge of the habitable zone for planets with rapid obliquity variations. We run EBM simulations for a range of values for the semi-major axis, assuming that the obliquity variations of the nominal system (terrestrial planet at 1 AU) are typical for each orbital architecture. We find that planets undergoing extreme axial perturbations may be habitable at larger distances than those with static obliquity. This extension arises because the obliquity variations suppress the build-up of ice sheets at the poles, reducing the effectiveness of the ice-albedo-temperature feedback. We also apply our model to the GI 581 g planet to explore these obliquity-climate feedbacks to a known system with potentially habitable planets.

221 *Habitability of a Terrestrial Planet* Special Session *Ballroom 6B*

221.01 On the Habitability of Gilese 581g Colin Goldblatt¹

¹University of Washington, on behalf of Virtual Planetary Laboratory. 2:00 PM - 2:15 PM

Ballroom 6B

The discovery of planet Gliese 581 g has provided a planet with an estimated mass 3 to 5 times that of Earth, that is apparently squarely in the "Habitable Zone" around its parent star. However, many factors contribute to planetary habitability, and a position within the habitable zone does not guarantee that the planet is able to support liquid water on its surface. In this work the NASA Astrobiology Institute's Virtual Planetary Laboratory lead team uses the known constraints for this planetary system to provide an interdisciplinary analysis of the degree to which Gliese 581 g is likely to be habitable. Making the assumption that Gliese 581 g can support liquid water at its surface, we additionally calculate and predict a plausible range of planetary characteristics, and reflectivity and emission spectra, for the planet.

221.02

Biological Modulation of Deep Earth Process Norm Sleep¹

¹Stanford University. 2:15 PM - 2:30 PM Ballroom 6B

The Earth became habitable once CO₂ could be subducted into the deep mantle. It is likely that the Earth's surface became clement or even frigid within a few million years after it cooled to habitable temperatures (less than ~120°C). Early life obtained its energy from chemical disequilibrium produced by internal processes within the Earth and photolysis in the air and water. The global productivity was tiny and life did not leave a useful record. By the time of the first good geological record at ~3.8 billion years, life had evolved anoxygenic (sulfide and ferrous iron) photosynthesis on both water and land. By then, the effects of life were so pervasive that it is not straightforward to infer the prebiotic environment; serpentine existed and catalysts including Ni₃Fe and Pt-group minerals were present in trace amounts. On land by 3.8 billion years ago, life had bountiful energy to enhance chemical weathering to liberate Fe(II). Microbial crusts covered available landscape. Life modulates crustal tectonics by producing sandstones, shales, and carbonates that form fold mountains. Melted shales became granitic rocks with quartz. The process is a climatic buffer as it replaced (black daisy) fresh basalts with (white daisy) sand deserts and granites. The subducted produces of photosynthesis control the sulfur content and oxidation state of arc lavas. Even the mantle is strongly affected by photosynthesis. Biology determines the mantle abundances of N and C. Kimberlites (in the general sense) return CO₂-rich subducted shallow oceanic crust and sediments to the surface. The chemistry of these rocks provides a record of surface conditions. It is likely that the mantle in general and kimberlites in particular sequester information on the earliest Earth that is no longer preserved in the crust.

221.03 Detecting Planetary Habitability Victoria Meadows¹

¹University of Washington, Seattle. 2:30 PM - 2:45 PM Ballroom 6B

The habitability of a planet depends on a myriad of stellar and planetary parameters, many of which we are just beginning to understand. Additionally, only a small fraction of these parameters are likely to be directly observable by the first, or even subsequent generations of astronomical telescopes. Our initial assays, will try to estimate the probability that a planet is habitable based on basic information such as mass and/or size of the planet, its orbital characteristics and information about its composition. To more definitively determine habitability, we must either directly detect large bodies of surface water, or attempt to constrain the surface temperature and pressure via a combination of observations and modeling. This presentation will summarize detection techniques and likely remote-sensing signs of habitability using techniques such as transmission spectroscopy and disk-integrated time-resolved photometry and spectra. We will also discuss the development of a "habitability factor", a means of combining stellar and planetary processes and relating them to observables to constrain the likely habitability of a discovered planet. This work is supported by the NASA Astrobiology Institute.

221.04

Planetary System Influences on Longterm Climatic Habitability

David S. Spiegel¹, S. N. Raymond², C. D. Dressing³

¹*Princeton University,* ²*Université de Bordeaux, France,* ³*Harvard University.*

2:45 PM - 3:00 PM

Ballroom 6B

The recent and growing realization that many exoplanetary systems have structures very different from our own motivates a reconsideration of what is meant by "Habitable." For instance, although the Earth's orbit is never far from circular, the architecture of exoplanet systems could cause some terrestrial planets around other stars to experience substantial changes in eccentricity. Eccentricity variations could lead to climate changes, including possible "phase transitions" such as the snowball transition (or its opposite). I will describe how giant planets on sufficiently eccentric orbits can excite extreme eccentricity oscillations in the orbit of a habitable terrestrial planet. This shows that the longterm habitability (and astronomical observables) of a terrestrial planet can depend on the detailed architecture of the planetary system in which it resides.

221.05

The Role of Tides in Planetary Habitability

Rory Barnes¹, R. Heller², B. Jackson³, J. Leconte⁴, R. Greenberg⁵, K. Mullins¹, S. N. Raymond⁶ ¹University of Washington, ²University of Hamburg, Germany, ³Goddard Space Flight Center, ⁴University of Lyon, France, ⁵University of Arizona, ⁶University of Bordeaux, France. 3:00 PM - 3:15 PM

Ballroom 6B

Terrestrial planets in the classic "habitable zone" (Kasting et al. 1993) of stars may be influenced by tides. Tidal evolution is poorly constrained and multiple acceptable models exist which, although qualitatively similar, predict different rates of evolution. Using different models, we examine how tides may modify several key properties of planets in the habitable zone: semi-major axis, eccentricity, obliquity and rotation rate. Tides can lock the rotation rate and erode the obliquity (to 0 or 180 degrees) in 10^3 - 10^{10} years, depending on the stellar mass and eccentricity. Some tidal models even predict

significant obliquity evolution for planets in the habitable zones of solar-mass stars. This evolution dissipates energy in the planet's interior (at the expense of the orbit) and leads to "tidal heating." In extreme cases of high eccentricity and very low mass stars, the heating may initiate a runaway greenhouse, and/or total evaporation of potential surface water, eliminating any hope of habitability. After the spin properties have equilibrated, the planet is said to be "tidally locked" and further evolution primarily changes the orbital angular momentum. For exoplanets, tides tend to reduce eccentricities and semi-major axes, and can also change the rotation period, eventually reaching synchroneity with the orbit when both eccentricity and obliquity reach zero. Orbital circularization requires millions to trillions of years, depending on the planet's initial conditions and the tidal model assumed. Tidal heating also occurs during circularization and planets may pass through a "super-lo" phase prior to reaching internal heating rates similar to the modern day Earth. Tides clearly have the potential to impact habitability and may lead to planets with evolutionary paths markedly different from the Earth. These issues are presented and discussed for the simple case of one planet orbiting one star.

221.06

MEarth: Looking for Transiting, Habitable Super-Earths whose Atmospheres Can Be Studied Zachory K. Berta¹, D. Charbonneau¹, J. Irwin¹, C. Burke¹, P. Nutzman¹, E. Falco² ¹Harvard University, ²Smithonsian Astrophysical Observatory. 3:15 PM - 3:30 PM

Ballroom 6B

M dwarfs, the most abundant stars in the Galaxy, offer a unique opportunity for the detection and atmospheric characterization of potentially habitable terrestrial planets. With the MEarth Project, we are using an array of modest telescopes to monitor the brightness of 2,000 nearby, late M dwarfs in a search for transiting, habitable super-Earths. Importantly, the favorable planet-to-star contrast ratios for planets found around M dwarfs would allow us to study the atmospheres of habitable super-Earths using techniques that have already been proven to work for hot Jupiters around Sun-like stars. I overview the current status and future plans of the MEarth Project, as well as recent and ongoing efforts to probe the atmospheric composition of the warm super-Earth GJ1214b - MEarth's first discovered planet.

222

Surveys and Large Programs Oral Session Ballroom 6C

222.01

The Panchromatic Hubble Andromeda Treasury: An HST Multicycle Map of M31 Julianne Dalcanton¹, PHAT Collaboration

¹Univ. of Washington. 2:00 PM - 2:10 PM Ballroom 6C

The Panchromatic Hubble Andromeda Treasury is an HST multicycle program to image the north east quadrant of M31 to deep limits in the UV, optical, and near-IR. The planned HST imaging will eventually resolve the galaxy into more than 100 million stars, all with common distances and foreground extinctions. UV through NIR stellar photometry (F275W, F336W with WFC3/UVIS, F475W and F814W with ACS/WFC, and F110W and F160W with WFC3/NIR) provides effective temperatures for a wide range of spectral types, while simultaneously mapping M31's extinction. Our central science drivers are to: understand high-mass variations in the stellar IMF as a function of SFR intensity and metallicity; capture the spatially-resolved star formation history of M31; study a vast sample of stellar clusters with

a range of ages and metallicities. These are central to understanding stellar evolution and clustered star formation; constraining ISM energetics; and understanding the counterparts and environments of transient objects (novae, SNe, variable stars, x-ray sources, etc.). As its legacy, this survey adds M31 to the Milky Way and Magellanic Clouds as a fundamental calibrator of stellar evolution and star-formation processes for understanding the stellar populations of distant galaxies. I will briefly describe our first season of data acquisition (including both the HST imaging and accompanying Keck spectroscopy), data reduction, and first science results.

222.02

Status and Early Science from the PS1 Science Mission Kenneth C. Chambers $^{\rm 1}$

¹Institute for Astronomy, University of Hawaii. 2:10 PM - 2:20 PM

Ballroom 6C

PS1, the Pan-STARRS Telescope No. 1 began the PS1 Science Mission May 13, 2009. Operations of the PS1 System, including the Observatory, Telescope, 1.4 Gigapixel Camera, Image Processing Pipeline, PSPS relational database and science specific software clients are presently funded for 2.5 years by PS1 Science Consortium.

The PS1 Surveys include: (1) A 3pi Steradian Survey, (2) A Medium Deep survey of 11PS1 footprints spaced around the sky; (3) A solar system survey optimized for Near Earth Objects, (4) a Stellar Transit Survey; and (5) a Deep Survey of M31. As of October, 2010, the PS1 3pi Survey has covered half the sky above a declination of -30 in five bands with 2 or more images. By the time of the AAS meeting, PS1 will have covered 0.75 of the available sky, or about 20,000 square degrees. The coverage, cadence, and data quality of the surveys and the current performance of the PS1 System will be presented. Early science results will be outlined. Transient data release to the community will be described, as well as the eventual release of all PS1 data.

The PS1 Science Consortium consists of The Institute for Astronomy at the University of Hawai'i in Manoa, the Max Planck Institute for Astronomy, Heidelberg and the Max Planck Institute for Extraterrestrial Physics, Garching, The Johns Hopkins University, the University of Durham, the University of Edinburgh, the Queen's University Belfast, the Harvard-Smithsonian Center for Astrophysics, the Los Cumbres Observatory Global Telescope Network Incorporated, the National Central University of Taiwan, and NASA.

The Pan-STARRS construction project is led by the University of Hawaii Institute for Astronomy with funding support from the United States Air Force Research Laboratory and contributions from the Maui High Performance Computing Center and MIT Lincoln Laboratory."

222.03

Progress on the Construction of The PS2 Telescope Jeffrey S. Morgan¹

¹Univ. of Hawaii, Institute for Astronomy, PanSTARRS.

2:20 PM - 2:30 PM

Ballroom 6C

The PS2 telescope is the second in a series of 4 telescopes that are being fabricated for the Pan-STARRS project. Its fabrication is currently in progress and this talk will discuss the current state of this fabrication. The optics for this telescope consist of the primary and secondary mirrors along with 3 large corrector lenses. These have already been purchased from Rayleigh Optical Corporation and are mostly complete. We will show the interferometric measurements of the completed elements. The site and enclosure for PS2 have been chosen to be the old LURE north dome which sits adjacent to the current

PS1 telescope on Haleakala, Maui. We will show design renderings for the renovations of this enclosure for the PS2 telescope. The design of the PS2 telescope has small, but significant differences that have been initiated by our experience with PS1. We will discuss these changes. Finally, we will discuss the fabrication schedule for PS2.

The Pan-STARRS construction project is led by the University of Hawaii Institute for Astronomy with funding support from the United States Air Force AFRL and in partnership with the Maui High Performance Computing Center and MIT Lincoln Laboratory.

222.04D

Transients in the Local Universe: Bridging the Gap between Novae and Supernovae Mansi M. Kasliwal $^{\rm 1}$

¹Caltech.

2:30 PM - 2:50 PM

Ballroom 6C

For the past several decades, there has existed a glaring six-magnitude luminosity gap between the brightest novae and faintest supernovae. To find optical transients that are fainter, faster and rarer than supernovae, we designed a systematic search -- "Palomar Transient Factory". Theorists predict a variety of mechanisms to produce transients in the gap and observers have the best chance of finding them in the local universe. Here I will present discoveries and unique physics of cosmic explosions that bridge this gap between novae and supernovae. This small number of intensively followed-up discoveries sets the stage for population studies with the upcoming "Large Synoptic Survey Telescope". This effort works towards building a complete inventory of transients in the local universe (d < 200 Mpc). It better prepares us for the search for potential electromagnetic counterparts to events in the emerging fields of gravitational wave, neutrino, TeV and UHECR astronomy.

222.05

The SDSS-XDQSO quasar targeting catalog

Jo Bovy¹, J. F. Hennawi², D. W. Hogg¹, A. D. Myers³, N. P. Ross⁴

¹New York University, ²Max-Planck-Institut fuer Astronomie, Germany, ³University of Illinois at Urbana-Champaign, ⁴Lawrence Berkeley National Lab.

2:50 PM - 3:00 PM

Ballroom 6C

We present the SDSS-XDQSO quasar targeting catalog for efficient flux-based quasar target selection down to the faint limit of the SDSS catalog, even at medium redshifts (2.5 <~ z <~ 3). We build models of the distributions of stars and quasars in flux space down to the flux limit by applying the extremedeconvolution method (XD) to estimate the underlying density. We properly convolve this density with the flux uncertainties when evaluating the probability that an object is a quasar. This results in a targeting algorithm that is more principled, more efficient, and faster than other similar methods. We apply the algorithm to derive low- (z < 2.2), medium- (2.2 <= z 3.5) quasar probabilities for all 160,904,060 point-sources with dereddened i-and magnitude between 17.75 and 22.45 mag in SDSS Data Release 8. The catalog can be used to define a uniformly selected and efficient low- or mediumredshift quasar survey, such as that needed for the SDSS-III Baryon Oscillation Spectroscopic Survey project. We show that the XDQSO technique performs as well as the current best photometric quasar selection technique at low redshift, and out-performs all other flux-based methods for selecting the medium-redshift quasars of our primary interest.

Research supported by NASA (grant NNX08AJ48G) and the NSF (grant AST-0908357).

222.06

The Angular Power-spectrum of SDSS Quasars Photometrically Classified through Extreme Deconvolution

Adam D. Myers¹, J. Bovy², S. Ho³, V. Martin⁴, D. W. Hogg², J. F. Hennawi⁵, A. Slosar⁶, M. White⁴, D. J. Schlegel³, R. J. Brunner¹, L. Verde⁷, V. V. Kindratenko⁸, N. Ross³, D. H. Weinberg⁹, M. A. Strauss¹⁰, D. P. Schneider¹¹, N. A. Bahcall¹²

¹University of Illinois at Urbana-Champaign, ²New York University, ³Lawrence Berkeley National Lab, ⁴UC Berkeley, ⁵Max-Planck-Institut für Astronomie, Germany, ⁶Brookhaven National Laboratory, ⁷Universitat de Barcelona, Spain, ⁸NCSA, ⁹Ohio State University, ¹⁰Princeton University Observatory, ¹¹Pennsylvania State University, ¹²Princeton University.

3:00 PM - 3:10 PM

Ballroom 6C

We apply the extreme-deconvolution method of Bovy et al. (2010, in preparation) to DR7 imaging from the Sloan Digital Sky Survey and derive a photometrically classified catalog of quasars in the redshift range 0.5 < z < 2.5. Our method is highly efficient, allowing nearly one million quasars to be classified with over 90% efficiency to faint magnitudes. For each object classified as a quasar, we use an instance-based approach to derive a full photometric redshift in the form of a probability density function (PDF). These PDFs allow a quantitative determination of whether objects lie in arbitrary redshift ranges (rather than at a single redshift or in a specific redshift range). The high efficiency of our catalog allows us to place new constraints on the large-scale geometry of the universe over the largest area to date using quasars in SDSS DR8 employing a matrix-based method that uses an optimal quadratic estimator. This provides a minimum-variance measurement of the clustering power. The vast area probed by our catalog is particularly interesting for measurements where statistics are mostly limited by cosmic variance. In particular, our approach provides an opportunity to place powerful new constraints on non-Gaussianity through the fNL parameter.

222.07

Angular Clustering of SDSS III DR8 photometric Luminous Red Galaxies

Shirley Ho¹, A. Cuesta², A. Ross³, N. Padmanabhan², M. White⁴, D. Schlegel¹, W. Percival³, F. Prada⁵, L. Verde⁶, R. Skibba⁷, Y. Lin⁸, O. Mena⁶, S. Saito⁹, N. Ross¹

¹Lawrence Berkeley Lab, ²Yale University, ³Institute of Cosmology and Gravitation, University of Portsmouth, United Kingdom, ⁴University of California at Berkeley, ⁵Instituto de Astrofisica de Andalucia, Spain, ⁶Instituto de Ciencias del Cosmos, Spain, ⁷Steward Observatory, University of Arizona, ⁸Institute of Physics and Mathematics of the Universe, Japan, ⁹University of California Berkeley. 3:10 PM - 3:20 PM

Ballroom 6C

We present the 2D angular power-spectrum of the Luminous Red Galaxies (LRGs) selected from SDSS III -DR8 data release. It consists of ~12,000 sq deg, more than 1.5 million LRGs, making it the largest volume ever used for a galaxy clustering measurement. These LRGs have accurate photometric redshifts, enabling us to reconstruct the 3D power-spectrum from their angular power-spectrum. We present initial cosmological constraints from these data.

223

HEAD: New Radio Insights in High Energy Phenomena Special Session Room 611/612

223.01

The Distance, Mass, and Spin of the Black Hole in Cyg X-1

Mark J. Reid¹, J. E. McClintock¹, R. Narayan¹, L. Gou¹, R. A. Remillard², J. A. Orosz³ ¹Harvard-Smithsonian, CfA, ²MIT Kavli Institute for Astrophysics and Space Research, ³San Diego State University.

2:00 PM - 2:15 PM

Room 611/612

It is critical to know the distance to an object if one wants to determine its physical characteristics. We report a rock-solid and precise measurement of the distance to the high-mass X-ray binary Cyg X-1, which contains the first black hole to be discovered. The distance was obtained by trigonometric parallax, using the Very Long Baseline Array, and has an uncertainty of 6%. This firm result allows accurate modeling of the system,

which yields both precision estimates of the physical characteristics of the binary system and a complete description of the black hole primary via measurements of its mass and spin.

223.02

Trawling Transients with LOFAR

Ralph A. M. J. Wijers¹

¹University of Amsterdam, Netherlands.

2:15 PM - 2:30 PM

Room 611/612

The LOFAR radio telescope is a wide-field radio interferometer operating in the 10-240 MHz range, with baselines from 50m to 1000km. It will be a multi-purpose fully open observatory, which will however devote significant time and effort to completing key science projects that drove its design. It has started commissioning operations and is expected to start its first all-sky shallow survey near the end of 2010. The Transients Key Science Project aims to monitor all LOFAR imaging data streams for transient and variable sources down to 1-sec timescales, and beam-formed (pulsar) data for even shorter events. A special extension to the project, the AARTFAAC experiment, will use the inner 350-m area for all-time all-sky imaging of the radio sky, down to sub-Jy levels. I will report on the current status and first results of LOFAR, and especially the Transients KSP.

223.03

Probing Stellar, Substellar and Exoplanetary Magnetospheres with Next Generation Radio Instruments Gregg Hallinan 1

¹NRAO and UC Berkeley. 2:30 PM - 2:45 PM Room 611/612

One of the most significant discoveries in stellar radio astronomy was the confirmation that cool dwarf flare stars can be persistent sources of non-thermal radio emission. With the commissioning of the EVLA, the potential exists to finally fully understand the means by which such non-thermal coronae are generated and sustained. Along with the expected increase in the sample of known objects, the capability to achieve continuous spectra covering 1-50 GHz, enables a robust assessment of the emission processes involved in the associated radio emissions. These observations can be coupled with recently developed spectropolarimetric techniques to simultaneous assess the strength and configuration of the

magnetic fields. I will discuss plans to commence such observations as well as studies of radio emissions from brown dwarfs and exoplanets achievable with EVLA and LOFAR respectively.

223.04

Imaging the Gamma-ray and X-ray Emission Regions of Blazars with the VLBA Alan P. $\mbox{Marscher}^1$

¹Boston Univ.. 2:45 PM - 3:00 PM

Room 611/612

The wight date:

The richly detailed X-ray and gamma-ray light curves provided by RXTE, the Fermi LAT, and Cherenkov telescopes have the potential of greatly enhancing our understanding of high-energy phenomena in the relativistic jets of blazars. In order to translate the time domain into 3-D pictures of jets, though, we need the ultra-high angular resolution of the VLBA and global VLBI at millimeter wavelengths. We can correlate changes in VLBA images with outbursts and quiet periods in the gamma-ray and X-ray light curves and use the time delays - or lack thereof - to locate the high-energy emission relative to the bright, stationary feature in the images referred to as the "core."

The polarization capabilities of the VLBA allow direction comparison of variations in optical and near-IR polarization with those seen in features appearing in the mm-wave images. In many cases, close correlation between the optical/near-IR and high-energy light curves provides another way to associate the emission at all wavebands with the core or other stationary emission features, and superluminal knots. In addition, the polarization and its variations inform us on the magnetic field configuration. The presentation will show examples of how this combination of the VLBA and space-borne as well as ground-based telescopes is enlightening us on the origin and behavior of relativistic jets. The research reported in the presentation is supported by NASA grants NNX08AJ64G, NNX08AJ61G, NNX08AV65G, NNX08AW56G, NNX09AR11G, NNX09AT99G, and NNX10AL13G, and NSF grant AST-0907893.

223.05

New Insights Into the GRB Physics by Multiwaveband Modeling of their Radio Afterglows Chandra Poonam¹

¹Royal Military College of Canada, Canada.

3:00 PM - 3:15 PM

Room 611/612

After 6 years of operation, Swift has significantly advanced our physical understanding of gamma-ray bursts (GRBs) but it has also raised fundamental questions about the origin of the prompt emission, the nature of the central engine, and the character the relativistic outflow (i.e. composition, collimation, energy release, etc.) Sensitive radio measurements of GRB afterglow may play crucial role here. Radio afterglow measurements are useful for determining GRB energetics in two distinct ways. First, the signature of a jet break in a radio light curve is distinct but different than that seen in optical or X-ray light curves and is less affected by systematics. Thus the jet geometry information coming from radio data is quite robust. Radio data is most powerful when modeled as part of the multi-wavelength dataset. This gives us a reliable method to derive the blast wave kinetic energy and the density of the circumburst medium. Second, if the afterglow is bright enough, the radio data offers a unique way of determining the late-time GRB calorimetry. Our group has observed several hundred GRBs in radio band with the VLA. Here I will talk about how these radio observations combined with other multiwaveband observations have increased our overall understanding towards the GRB Physics. Reverse shocks seen in some radio afterglows have given us new insights in early Physics of GRBs. Towards the end I will talk

about the existing loopholes in our understanding of GRB phenomenon and how the upcoming telescopes such as EVLA and ALMA will fill these gaps.

224

Emerging Results on the Extreme Binary, epsilon Aurigae Special Session *Room 615/617*

224.01 Historical Perspective On the Study of Epsilon Aurigae Edward F. Guinan¹

¹*Villanova Univ..* 2:00 PM - 2:15 PM

Room 615/617

Epsilon Aurigae has been known since 1821 as an eclipsing binary with a 27 year period, but has defied interpretation for nearly 2 centuries. The high luminosity F star is eclipsed by an invisible companion, now recognized as a debris-like disk. I will briefly review prior ideas proposed by Struve, Eggleton and Huang and others, to set the stage for the remarkable revelations made possible during the current 2009-2011 eclipse.

224.02

Photometric Monitoring of Epsilon Aurigae in Eclipse

Jeff Hopkins¹ ¹*HPO Soft.* 2:15 PM - 2:30 PM *Room 615/617*

A remarkable and international ensemble of professional and amateur astronomers have combined efforts to report multi-color photometry as part of an eclipse monitoring campaign. I will exhibit the UBVRIJH light curves generated to date, discuss the structure in the light curves and comment on the degree to which these variations represent instabilities in the F star and/or longitudinal structure in the dark disk causing the eclipses.

224.03

Archival Spectroscopy of Epsilon Aurigae

R. E. M. Griffin¹

¹Herzberg Inst. of Astrophysics, Canada. 2:30 PM - 2:45 PM Room 615/617

Remarkable photographic high dispersion spectra of epsilon Aurigae in and out of eclipse have been collected at Mt. Wilson, Dominion Astrophysical Observatory. Many of these spectra are being digitized for modern analysis and thus provide unrepeatable material for studying variability on timescales of many decades, and given the presumption that the system will be capable of revealing changes associated with any relatively recent mass transfer.

224.04

Recent Spectroscopy of Epsilon Aurigae in Eclipse William F. Ketzeback¹ ¹Apache Point Observatory. 2:45 PM - 3:00 PM

Room 615/617

Modern digital spectroscopy of bright stars not only opens opportunities in asteroseismic and planet detection areas, but an eclipsing binary like epsilon Aurigae provides a CATscan-like dissection of the dark disk now transiting the super-large F star. I will report on optical and near-infrared spectroscopic monitoring being conducted at the ARC 4 meter at Apache Point Observatory and report on major changes in the spectra due to eclipse, assigning changes to the disk insofar as possible.

224.05

Interferometric Imaging of Epsilon Aurigae

Robert E. Stencel¹

¹Univ. of Denver. 3:00 PM - 3:15 PM Room 615/617

One of the remarkable advances since the 1983 eclipse of epsilon Aurigae is the maturation of interferometric imaging. I will report on a series of images obtained at the CHARA aary at Mt. Wilson since 2008 that show the encroachment of the dark disk, substructure in the disk and recent post-mid-eclipse phenomena.

224.06

Summary and the Future of Studies of Epsilon Aurigae

Brian K. Kloppenborg¹

¹University of Denver. 3:15 PM - 3:30 PM

Room 615/617

How does epsilon Aurigae fit into modern paradigms of stellar evolution, interacting binary stars and planet-forming disks? The next eclipse of epsilon Aurigae begins in 2036. I will attempt to forecast what additional inter-eclipse observations and theory will be useful, based on the panoply of results derived during the current eclipse cycle.

225

Gravitational Lenses and Gravitational Waves Oral Session *Room 618/620*

225.01

Placing Limits on Extragalactic Substructure with Gravitational Lenses and Adaptive Optics

David J. Lagattuta¹, S. Vegetti², M. W. Auger³, C. D. Fassnacht¹, L. V. E. Koopmans⁴, J. P. McKean⁵ ¹University of California, Davis, ²Kavli Institute for Astrophysics and Space Research, MIT, ³University of California, Santa Barbara, ⁴Kapteyn Institute, University of Groningen, Netherlands, ⁵ASTRON, Netherlands.

2:00 PM - 2:10 PM Room 618/620

We present the first results from a systematic search for extragalactic substructure, using high resolution Adaptive Optics (AO) images of known strong gravitational lenses. In particular we focus on two lens systems, B0128+437 and B1939+666, placing limits on both luminous and dark matter substructure, and presenting additional science that is only obtainable through the use of AO.

225.02

Probing Cosmology with Minkowski Functionals of Weak Lensing Maps

Jan Michael Kratochvil¹, E. A. Lim², S. Wang³, Z. Haiman⁴, M. May⁵, K. Huffenberger¹ ¹University of Miami, ²Institute for Strings, Cosmology, and Astroparticle Physics, Columbia University, ³Kavli Institute for Cosmological Physics, University of Chicago, ⁴Columbia University, ⁵Brookhaven National Laboratory.

2:10 PM - 2:20 PM

Room 618/620

Minkowski functionals (MFs) are alternative probes of non-Gaussianity of random fields and probe the morphology and topology. We apply them to constrain cosmological parameters from weak gravitational lensing maps. We use MFs with Monte Carlo-optimized threshold bins to distinguish between different cosmological models from simulated convergence maps. We find that MFs discern better than the power spectrum from the same maps, thus providing evidence that they probe nonlinear structure formation and measure information beyond the power spectrum. The lensing maps were created with our new huge Inspector Gadget lensing simulation pipeline on the IBM Blue Gene at Brookhaven National Laboratory, allowing us to create an extensive simulation suite of ninety 512³-particle N-body simulations and sample many cosmological models and initial conditions.

225.03

Searching For Gravitational-wave Signals From High-mass Compact Binaries With LIGO And Virgo Ilya Mandel¹, LIGO Scientific Collaboration, Virgo Collaboration

¹MIT.

2:20 PM - 2:30 PM

Room 618/620

The Laser Interferometer Gravitational-wave Observatory (LIGO) and Virgo are searching for the gravitational waves emitted during the inspiral and coalescence of binary systems composed of compact remnants: neutron stars and black holes. For relatively high-mass systems, a significant fraction of the signal-to-noise ratio will be contributed by the merger and ringdown portions of the waveform. We report on completed searches for high-mass compact-binary coalescences and present the observational results from these searches. We give an overview of ongoing high-mass searches being performed by the LIGO Scientific and Virgo collaborations. We also discuss future prospects as the instruments enter commissioning that will significantly enhance their sensitivity.

225.04

Implications Of Recent Observations For The Population Of Compact Galactic Binaries Observable By Lisa

Samaya Nissanke¹, G. Nelemans², T. Prince¹, M. Vallisneri¹ ¹Caltech/JPL, ²Radboud University Nijmegen, Netherlands. 2:30 PM - 2:40 PM

Room 618/620

Ultra compact galactic binaries, where at least one member is a white dwarf or neutron star, constitute the majority of LISA's individually detectable sources. In addition, they form the dominant unresolvable galactic foreground for LISA at frequencies below a few milliHertz. Furthermore, a handful of ultra-compact binaries, observed at optical, ultraviolet and X-ray wavelengths, are the only known verification sources, detectable by LISA within a few months of the start of its mission.

In the context of LISA, the majority of studies involving galactic binaries have been based on theoretical population synthesis, due to the paucity of electromagnetic observations. Recently, significant

observational progress has been made in detecting new systems of compact single or double white dwarf binaries.

We consider the impact of revised local space density estimates of compact white dwarf binaries on LISA observations.

Firstly, we show that the number of resolvable detached and semi-detached systems decreases. Secondly, depending critically on the white dwarf binary formation channel assumed, we investigate how the astrophysical foreground of galactic ultra compact binaries can decrease.

225.05

Error Sources for Gravitational Wave Sensors using Atom Interferometry Peter L. Bender $^{\rm 1}$

¹JILA, Univ. of Colorado and NIST.

2:40 PM - 2:50 PM

Room 618/620

Proposals have been made recently for using two atom interferometers in gravitational wave sensors with a quite long two-way laser link between them (see e.g. S. Dimopoulos et al., Phys. Rev. D 78, 122002 (2008)). However, it appears that an important error source has been overlooked in such proposals. This error source involves the combined effects of laser wavefront aberrations and of the radial velocities of the atoms in the cooled atom clouds used in the interferometers. These errors can be due to jitter from measurement to measurement in either the wavefront aberrations themselves or in the radial velocities of the atoms in the clouds.

In the AGIS-Satellite 3 proposal of Dimopoulos et al., the distance between the two spacecraft used would be 10,000 km, and the calculated sensitivity limit due just to shot noise in detecting the final state of the atoms in the interferometers is $3x10^{-22}/(Hz^{0.5})$ from 0.002 to 0.5 Hz. For a simplified model based only on primary spherical aberrations over 1 m diameter laser beams transmitted between the spacecraft and on 100 pK cloud temperatures, the extra noise would be equal to the calculated gravitational wave sensitivity for roughly the following disturbance levels: $2x10^{-6}$ wavelengths jitter in the aberration amplitude from second to second, or 0.1% fractional jitter in the rms radial atom velocities. However, the applicability of the model needs to be checked.

226

Multiple Cool and Brown Dwarfs Oral Session *Room 4C-2*

226.01

Discovery of the First Resolved Triple T-Dwarf

Jacqueline Radigan¹, R. Jayawardhana¹, D. Lafrenière², M. Liu³, T. Dupuy³

¹University of Toronto, Canada, ²Université de Montréal, Canada, ³Institute For Astronomy, University of Hawai'i.

2:00 PM - 2:10 PM

Room 4C-2

We present imaging and spectroscopy of a recently discovered triple T-dwarf system. This system, which has an unresolved spectral type of T3, was resolved into a 0.55" A(BC), and 0.05"(BC) components using the laser guide star adaptive optics at Keck during our program designed to check for unresolved binarity in early T-dwarfs whose near infrared colors span the L/T transition. This phase of brown dwarf evolution, characterized by the rapid disappearance of dust clouds over a very small range of brown dwarf effective temperatures and a corresponding brightening in the J-band remains poorly understood,

and is complicated by the fact that most observations of L/T transition objects are drawn from a heterogeneous sample, consisting of a high frequency of unresolved binaries, and spanning a wide range of ages and metallicities. As the first resolved triple T-dwarf, our system represents a unique laboratory for confronting evolutionary and atmospheric models of the L/T transition.

226.02D

High-contrast Adaptive Optics and a Search for Late-type Companions to Hyades FGK Dwarfs Katie M. Morzinski¹

¹University of California, Santa Cruz. 2:10 PM - 2:30 PM

Room 4C-2

The Hyades is an intermediate-age open cluster with hundreds of main-sequence stars and is thus wellsuited to stellar formation and evolution studies. Being nearby with high proper motion, it is a choice cluster for direct-imaging surveys. We conduct a high-contrast adaptive optics (AO) search for late-type companions as faint as M_H~15 (late-L/early-T) within 5-230 AU around 88 FGK main-sequence Hyades dwarfs. Departures from the ideal point-spread function (PSF) in the image plane are caused by phase and amplitude errors that redistribute stellar light and limit the achievable contrast. An AO system on a ground-based telescope mitigates the phase errors in the pupil, but constructive interference of spatially coherent light causes amplitude spikes in the PSF called speckles. The locally-optimized combination of images (LOCI) algorithm is used to identify and subtract the quasistatic speckles and static PSF structure, allowing imaging of faint point-source companions. We use LOCI on deep near-infrared AO Hyad imaging at Keck and Lick Observatories. Background objects are subsequently ruled out by comparing relative astrometry in two epochs separated by five years. We present our confirmed Hyades companions. Furthermore, we look ahead to AO for exoplanet-imaging wherein a "dark hole" in the PSF facilitates high-contrast imaging. The size of the dark hole is set by the highest spatial frequency controllable by the deformable mirror (DM). Decreasing rejection at increasing spatial frequencies reduces the correction efficiency within the high-contrast region, owing to the nature of the MEMS (micro-electro-mechanical systems) DM transfer function. This effect can be mitigated by a dual-DM "woofer/tweeter" AO system whereby each DM controls a different spatial frequency regime. We present empirical results on selecting a woofer DM in order to maintain the dark hole for the upcoming Gemini Planet Imager. (Supported by NASA Michelson Fellowship, NSF Center for Adaptive Optics, Moore Foundation, IGPP, LLNL/DoE.)

226.03

Low Mass Eclipsing Binaries in Sparsely Sampled Time-Domain Surveys: SDSS Stripe 82 Waqas Bhatti¹, M. W. Richmond², H. C. Ford¹, L. D. Petro³

¹Johns Hopkins University, ²Rochester Institute of Technology, ³Space Telescope Science Institute. 2:30 PM - 2:40 PM

Room 4C-2

Observations of a small sample of eclipsing binary systems composed exclusively of low mass stars (< 0.8 Msun, spectral type K and M) indicate that theoretical models of stellar structure and evolution (e.g. Baraffe et al. 1998) systematically under-predict the observed radii by ~10%. Tidal effects and rotation-induced magnetic fields in close binaries may be responsible for this disagreement, but the small observed sample of these objects presents difficulties in testing this hypothesis. Large scale time-domain surveys are an effective method for discovery and characterization of these intrinsically faint eclipsing binaries. Here, we present results of a search for periodic variables in multi-band sparsely sampled timeseries data from SDSS Stripe 82, including the discovery of ~200 eclipsing binary candidates. These include 51 K and 79 M-dwarf eclipsing binaries as classified by their SDSS colors. We discuss the general

properties of this sample, including the period, spectral type, and binary type distributions. For ~30 of these objects that have sufficient phase coverage and secure orbital period determinations, we model the SDSS riz-band light-curves using the Wilson-Devinney code (Wilson & Devinney 1971), and determine relative radii, temperatures, luminosities, and orbital inclinations. Finally, we identify 5 M-dwarf eclipsing binaries in this sample with median SDSS r < 18.0 mag that are particularly suitable for photometric and spectroscopic followup observations. These observations will result in precise measurements of the binary components' masses and radii, placing better constraints on the observed mass-radius relation of the lower main-sequence, and the extent of its disagreement with predictions from theoretical models.

Based on data from the Sloan Digital Sky Survey (http://www.sdss.org). This research was supported in part by NASA grant NAG5-7697.

226.04D

Desert Dwellers and Dynamic Duos: Short-Period Brown Dwarf Companions and Binary Science with Exoplanet Surveys

Scott W. Fleming¹, J. Ge¹

¹Univ. Of Florida. 2:40 PM - 3:00 PM

Room 4C-2

Exoplanet transit and Doppler surveys detect many binary stars and brown dwarf companions with relative ease because the observational signatures are 1-2 orders of magnitude larger than planets. These objects allow for studies of several ancillary science topics, such as the two brown dwarf deserts and the mass-radius relationship of stars. In this dissertation talk, I will present my thesis work on conducting these studies using data from the MARVELS survey and several transit survey databases. I will present the discovery of two short-period (P < 10 days) brown dwarf companions to main sequence stars discovered during the MARVELS survey and its Pilot Project. Although I will focus on these two brown dwarfs, the MARVELS survey has already discovered a dozen brown dwarf companions that will serve to characterize the dryness of the brown dwarf deserts. These discoveries are needed to better understand brown dwarf formation and dynamical evolution histories. I will then present results from my work on cross-referencing spectroscopic binaries found in the MARVELS survey with archival photometry to conduct studies of the mass-radius relationship. Finally, I will present spectroscopic observations of known eclipsing binaries from transit surveys using the EXPERT instrument at the KPNO 2.1m telescope.

226.05D

The Brown Dwarf Kinematics Project (BDKP): How Distances Both Advance and Complicate Our Understanding of the Brown Dwarf Population

Jacqueline Faherty¹, A. J. Burgasser², F. M. Walter³, N. S. van der Bliek⁴, M. M. Shara⁵, K. L. Cruz⁶, F. J. Vrba⁷, S. J. Schmidt⁸, A. A. West⁹

¹Stony Brook Univ./American Museum of Natural History, ²UCSD, ³Stony Brook Univ., ⁴CTIO, Chile, ⁵American Museum of Natural History, ⁶Hunter College, ⁷USNO, ⁸University of Washington, ⁹Boston University.

3:00 PM - 3:20 PM

Room 4C-2

The distances and kinematics of brown dwarfs provide key statistical constraints on their ages, moving group membership, absolute brightnesses, evolutionary trends, and multiplicity. Yet fundamental measurements of parallax, proper motion and radial velocity have been made for only a relatively small fraction of the known brown dwarf population. To address this deficiency, we initiated the Brown Dwarf

Kinematics (BDKP) which aims to measure and compile the 6D positions and velocities of all known brown dwarfs within 20 pc of the Sun and select sources of scientific interest. For the past four years we have been collecting parallax data on 84 ultracool dwarfs including 17 late-type M and L dwarfs demonstrating spectral signatures of youth, 3 subdwarfs, and 12 L/T transition objects, using the ANDICAM and ISPI imagers on the 1.3m and 4.0m telescopes (respectively) at CTIO. Combining our measurements with those from the literature, we re-examine color-magnitude and spectrophotometric relations as well as prominent color trends for the brown dwarf population. Using absolute magnitude relations in J,H, and K, we identify overluminous binary candidates and investigate known flux-reversal binaries. Using current evolutionary models, we compare the MK vs J-K color magnitude diagram to model predictions and find the low-surface gravity dwarfs are significantly redward and underluminous of predictions and a handful of late-type T dwarfs may require clouds to account for the observed scatter in absolute magnitude.

226.06

The MuGSHoTS Program, Multiplicity for Galactic Stars of the Halo and Traceable Systems: First Detection of Low-mass, Metal-Poor Pairs with Mappable Orbits.

Sebastien Lepine¹, R. M. Rich²

¹American Museum of Natural History, ²UCLA.

3:20 PM - 3:30 PM

Room 4C-2

We present the first results from the MuGSHoTS program, a systematic search for double/multiple systems in a well-defined sample of ~1,000 Galactic halo stars (high-velocity subdwarfs) located within 80 parsecs of the Sun. The survey combines wide field, common proper motion searches with high-resolution adaptive optics imaging from the Lick and Keck observatories, and additional imaging data from the Hubble Space Telescope. The primary goals are to (A) calculate the multiplicity fraction among low-mass halo stars in order to study the formation and survivability of Pop.II binaries, and (B) identify benchmark systems in which the masses of old, metal-poor stars could be directly measured by monitoring the orbital motion of the components. We report the discovery and confirmation of four relatively tight binary systems with projected orbital separations <100AU and very cool, low-mass stellar components (late-M subdwarfs).

Support for this program was provided by NASA through a grant from the Space Telescope Science Institute, operated by AURA Inc., under NASA contract NAS5-26555, and though a grant from the California Institute of Technology, Jet Propulsion Laboratory.

227 *Galaxy Clusters: Lensing and S-Z Effect* Oral Session *Room 606*

227.01

Quantifying substructure in Galaxy Clusters with X-ray and Gravitational Lensing Measurements. Sanghamitra Deb¹, R. Nakajima², R. Mandelbaum³, G. Bernstein⁴, D. M. Goldberg⁵ ¹Lawrence Berkeley National Laboratory, ²University of California, Berkeley, ³Princeton University, ⁴University of Pennsylvania, ⁵Drexel University.

2:00 PM - 2:10 PM

Room 606

Clusters of galaxies are among the richest astrophysical objects. In order to understand the substructure in galaxy clusters we measure the higher order moments of the X-ray temperature distribution and the lensing mass distribution. The lensing mass distribution is reconstructed using Particle Based Lensing.

This is a new technique that combines Strong and Weak (S+W) lensing using variable resolution in an optimal fashion. We do a detailed S+W lensing analysis of A1689 and find significant substructure in core of the dark matter distribution compared to a smooth X-ray temperature distribution. This suggests that the outer region of the cluster is fairly relaxed whereas the dark matter halos in the inner cores are still active. This is also supported by the distribution of galaxies in the optical data. Currently we are doing a similar analysis for 20 supermassive clusters in the local universe. This sample of clusters have exsiting X-ray data from Chandra, XMM and ASCA X-ray, strong lensing data from HST and weak lensing data from SUBARU or MMT. We will present preliminary results on the comparison of the lensing mass distributions and the X-ray temperature distributions for this sample.

227.02

Precision Galaxy Cluster Mass Estimates with Weak Gravitational Lensing

Reiko Nakajima¹, R. Mandelbaum², G. Bernstein³, C. J. MacDonald³, S. Deb⁴ ¹UC Berkeley, ²Princeton University, ³University of Pennsylvania, ⁴LBL. 2:10 PM - 2:20 PM

Room 606

Clusters of galaxies are the largest collapsed structures in the universe. Their size and distribution provide cosmological information, while their internal dynamics provide astrophysical clues to galaxy formation and evolution. In both cases, an accurate estimate of the mass of these clusters is crucial in tying the theory to observation. Here we present an ongoing project where we carefully measure the masses of 20 of the most massive clusters in 0.15<z<0.3, using the weak gravitational lensing (WL) technique. We supplement ground-based, high-resolution images of galaxies (whose shape provide the distortion information due to gravitational lensing) with 5-band photometry, to obtain photometric redshifts (photo-z) of these galaxies. The photo-z provide lensing signal calibration accuracy of <1%. Our goal is to provide accurate mass estimates on individual galaxy clusters, to quantify the relation and scatter between mass estimates based on X-ray temperatures. Based on astrophysical calculations, X-ray temperature mass estimates have an estimated ~20% scatter in its relation to the true mass. This information can then used to relate the mass functions of galaxy clusters between theory and observation. The standard disclaimer is that WL mass estimates, while having no dependence on gas physics or non-equibrium conditions, suffer from other systematics, such as mass projection effects. Our mass calibration will take these systematics into consideration to obtain the best estimate on the Xray observable/cluster mass relation and scatter.

227.03D

Measuring Sunyaev-Zel'dovich Scaling Relations with APEX-SZ

Amy N. Bender¹, APEX-SZ Collaboration

¹University of Colorado-Boulder.

2:20 PM - 2:40 PM

Room 606

Accurately measuring the masses of galaxy clusters is critical to the precise constraint of cosmological parameters from cluster surveys. The Sunyaev-Zel'dovich effect (SZE) is expected to be an excellent proxy for total cluster mass as it is relatively insensitive to the complicated physical processes internal to the cluster. The SZE also provides a unique opportunity for cluster surveys as the signal does not suffer from cosmological dimming. I present SZE observations taken with the 150 GHz APEX-SZ imaging camera; a 280 element transition edge sensor bolometer array mounted on the APEX telescope in northern Chile. Over the course of six observing campaigns we have acquired 575 hours of integration time on 36 targeted clusters. This sample contains both merging and relaxed clusters, and spans a wide

range of redshifts and X-ray temperatures. I will present scaling relations relating the integrated SZE flux and X-ray temperature and $(Y-T_x)$ and compare them with predictions from numerical simulations.

227.04D

Sunyaev-Zel'dovich Observations of Strong Lensing Galaxy Clusters

Megan B. Gralla¹, M. D. Gladders¹, K. Sharon², SZA Collaboration, SGAS Collaboration, RCS Collaboration ¹University of Chicago, ²Kavli Institute for Cosmological Physics.

2:40 PM - 3:00 PM

Room 606

We have conducted Sunyaev-Zel'dovich (SZ) observations of strong lensing selected galaxy clusters using the Sunyaev Zel'dovich Array (SZA), which is part of the Combined Array for Research in Millimeter-wave Astronomy. The SZA is an 8-element interferometer that operates at 30 and 90 GHz. The SZA is sensitive to scales of a few arcminutes, while strong lensing mass modeling constrains the mass at small scales (typically < 30"). Combining the two provides information about the projected concentrations of the strong lensing clusters, which we compare with theoretical expectations. We also compare the shapes and orientations of the clusters' SZ signals with the locations of the lensed images and with the shapes and orientations of the brightest cluster galaxies.

227.05D

Probing Cluster Cores Through High Resolution Sunyaev-Zel'dovich Imaging From MUSTANG And The GBT

Phillip Korngut¹, S. Dicker¹, E. D. Reese¹, B. S. Mason², M. J. Devlin¹, T. Mroczkowski¹, C. L. Sarazin³, M. Sun³

¹Univ. of Pennsylvania, ²National Radio Astronomy Observatory, ³Univ. of Virginia. 3:00 PM - 3:20 PM

Room 606

The SZ effect in galaxy clusters has long been sought as a cosmological probe. Typically, measurements are made at ~arcminute resolution to match the angular extent of the bulk signal in clusters. This is desirable when using the effect to search for clusters, or to extract physical parameters from radial profiles. However, as the SZ signal directly traces the line of sight integrated pressure, measuring the SZ on smaller angular scales provides a unique probe of pressure micro-physics in the cores which will be missed at lower resolution. I will present SZ observations of 4 massive galaxy clusters taken with the MUSTANG receiver on the GBT. These new measurements reveal pressure substructure in 3 of the 4 systems. In one high redshift system, we find strong evidence for a mildy supersonic merger induced shock front, and through a simultaneous analysis of X-ray and SZ, model the dynamics of the merger. In contrast, a nominally relaxed cluster with a known cool core was mapped and deemed consistent with no obvious substructure.

227.06

CLASH: Cluster Lensing and Supernova survey with Hubble.

Marc Postman¹, D. Coe¹, H. Ford², A. Riess¹, W. Zheng², M. Donahue³, L. Moustakas⁴, CLASH Team ¹STScl, ²JHU, ³MSU, ⁴JPL/Caltech.

3:20 PM - 3:30 PM

Room 606

We occupy a "dark" Universe where 23% of its mass-energy density is made up of weakly interacting (and, as yet, undetected) non-baryonic particles (a.k.a. dark matter) and 72% is as yet unknown physics (a.k.a. dark energy) that is driving an accelerated expansion. To shed new light on these mysteries, we have been awarded 524 orbits of time to conduct a multi-year program with the Hubble Space Telescope that will couple the gravitational lensing power of 25 massive intermediate redshift galaxy

clusters with HST's newly enhanced panchromatic imaging capabilities (WFC3 and a restored ACS) to test structure formation models with unprecedented precision. The HST observations, combined with existing wide-field imaging, represent a giant advance in the quality and quantity of strong lensing data, enabling us to measure the dark matter (DM) mass profile shapes and mass concentrations from hundreds of multiply imaged sources, providing precise (~10%) observational challenges to scenarios for the DM mass distribution. The strongly lensing clusters in our sample give us a tenfold advantage over field surveys in identifying galaxies with z >7 for which spectra can be obtained with large ground-based telescopes. In parallel with this lensing survey, we will use both ACS and WFC3/IR to detect type-la supernovae (SNe Ia) in the space-unique redshift range 1 < z < 2. Because the SNe Ia will be detected when these cameras are in parallel, they will be far from the cluster core where the effects of lensing are small (and correctable), making the SNe usable for improving the limits on the redshift variation of the dark energy equation of state. We present the science that will be addressed with our survey and some of the preliminary data obtained with HST.

228

The Center for Astronomy Education (CAE) Collaboration of Astronomy Teaching Scholars (CATS) Program: A Year-Three Research Update Special Session *Room 608*

228.01

The Effect of Interactive Instruction in the Astro 101 Classroom: Report on a National Study Alexander L. Rudolph¹, E. E. Prather², G. Brissenden², D. Consiglio³, W. M. Schlingman², V. Gonzaga¹, Collaboration of Astronomy Teaching Scholars (CATS)

¹California State Polytechnic Univ., ²Center for Astronomy Education (CAE), Steward Observatory, Univ. of Arizona, ³Bryn Mawr College.

2:00 PM - 2:15 PM

Room 608

We have conducted a national research study designed to determine the effect of interactive learning strategies on students' conceptual learning in general education astronomy courses (Astro 101). Nearly 4000 students at 31 institutions, (4-year and 2-year) around the country participated in the study. Our results show dramatic improvement in student learning with increased use of interactive learning strategies independent of institution type or class size, and after controlling for individual student characteristics. In addition, we find that the positive effects of interactive learning strategies apply equally to men and women, across ethnicities, for students with all levels of prior mathematical preparation and physical science course experience, independent of GPA, and regardless of primary language. These results powerfully illustrate that all categories of students can benefit from the effective implementation of interactive learning strategies.

This material is based upon work supported by the National Science Foundation under Award No. 0715517, a CCLI Phase III Grant for the Collaboration of Astronomy Teaching Scholars (CATS) Program, and Award No. 0847170, a PAARE grant funding the California-Arizona Minority Partnership for Astronomy Research and Education (CAMPARE). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

228.02D

Using Classical Test Theory and Item Response Theory to Evaluate the LSCI

Wayne M. Schlingman¹, E. E. Prather¹, Collaboration of Astronomy Teaching Scholars (CATS) ¹Center for Astronomy Education (CAE), Steward Observatory, Univ. of Arizona.

2:15 PM - 2:30 PM

Room 608

Analyzing the data from the recent national study using the Light and Spectroscopy Concept Inventory (LSCI), this project uses both Classical Test Theory (CTT) and Item Response Theory (IRT) to investigate the LSCI itself in order to better understand what it is actually measuring. We use Classical Test Theory to form a framework of results that can be used to evaluate the effectiveness of individual questions at measuring differences in student understanding and provide further insight into the prior results presented from this data set. In the second phase of this research, we use Item Response Theory to form a theoretical model that generates parameters accounting for a student's ability, a question's difficulty, and estimate the level of guessing. The combined results from our investigations using both CTT and IRT are used to better understand the learning that is taking place in classrooms across the country. The analysis will also allow us to evaluate the effectiveness of individual questions and determine whether the item difficulties are appropriately matched to the abilities of the students in our data set. These results may require that some questions be revised, motivating the need for further development of the LSCI. This material is based upon work supported by the National Science Foundation under Grant No. 0715517, a CCLI Phase III Grant for the Collaboration of Astronomy Teaching Scholars (CATS). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

228.03

The Question Complexity Rubric: Development and Application for a National Archive of Astro 101 Multiple-Choice Questions

Sebastien Cormier¹, E. E. Prather¹, G. Brissenden¹, Collaboration of Astronomy Teaching Scholars (CATS) ¹Center for Astronomy Education (CAE), Steward Observatory, Univ. of Arizona. 2:30 PM - 2:45 PM

Room 608

For the last two years we have been developing an online national archive of multiple-choice questions for use in the Astro 101 classroom. These questions are intended to either supplement an instructor's implementation of Think-Pair-Share or be used for assessment purposes (i.e. exams and homework). In this talk we will describe the development, testing and implementation of the Question Complexity Rubric (QCR), which is designed to guide the ranking of questions in this archive based on their conceptual complexity. Using the QCR, a score is assigned to differentiate each question based on the cognitive steps necessary to comprehensively explain the reasoning pathway to the correct answer. The lowest QCR score is given to questions with a reasoning pathway requiring only declarative knowledge whereas the highest QCR score is given to question archive will provide users with the utility to 1) search for and download questions based on subject and average QCR score, 2) use the QCR to score questions, and 3) add their own questions to the archive. We will also discuss other potential applications of the QCR, such as how it informs our work in developing and testing of survey instruments by allowing us to calibrate the range of question complexity.

This material is based upon work supported by the National Science Foundation under Grant No. 0715517, a CCLI Phase III Grant for the Collaboration of Astronomy Teaching Scholars (CATS). Any

opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

228.04

Development and Testing of the Solar System Concept Inventory

Seth D. Hornstein¹, E. E. Prather², T. R. English³, S. M. Desch³, J. M. Keller⁴, Collaboration of Astronomy Teaching Scholars (CATS)

¹Univ. of Colorado at Boulder, ²Center for Astronomy Education (CAE), Steward Observatory, Univ. of Arizona, ³Guilford Technical Community College, ⁴California Polytechnic State Univ. 2:45 PM - 3:00 PM

Room 608

Trying to assess if our students really understand the ideas we present in class can be difficult. Concept inventories are research-validated assessment tools that can provide us with data to better understand whether we are successful in the classroom. The idea for the Solar System Concept Inventory (SSCI) was born after realizing that no concept inventory currently available covered details regarding the formation and evolution of our solar system. Topics were selected by having faculty identify the key concepts they address when teaching about the solar system and interviewing students in order to identify common naive ideas and reasoning difficulties relating to these key topics. Beginning in fall of 2008, a national multi-institutional field test began which would eventually involve nearly 2500 students and 17 instructors from 10 different institutions. After each round of testing, a group of instructors from multiple institutions around the country worked together to analyze the data and revise or eliminate underperforming questions. Each question was examined using a combination of point biserial, percent correct on the pre-test, and item difficulty to determine if the question was properly differentiating student understanding while also ensuring the question was not too easy or too hard. In this talk, I will present an overall outline of the development of the SSCI as well as the final testing results. The final version of the SSCI can be found at http://casa.colorado.edu/~hornstei/ssci/. This material is based upon work supported by the National Science Foundation under Grant No. 0715517, a CCLI Phase III Grant for the Collaboration of Astronomy Teaching Scholars (CATS). Any findings expressed in this material are those of the authors and do not necessarily reflect the views of the NSF.

228.05

Student Learning from Interactive Software

Kevin M. Lee¹, Collaboration of Astronomy Teaching Scholars (CATS)

¹Univ. of Nebraska.

3:00 PM - 3:15 PM

Room 608

For several years at the University of Nebraska we have been developing interactive software to teach introductory astronomy. This software includes the simulations of the Nebraska Astronomy Applet Project, the computer database of visual Think-Pair-Share questions and resources for feedback known as ClassAction, and a library of animated ranking and sorting tasks. All of these projects are publicly available for use over the web or download at http://astro.unl.edu.

This presentation will highlight examples of research into student learning using these materials. Results from a multi-institution study of ClassAction using the Light and Spectra Concept Inventory in a pre/post format will be shown. Results from a second study on student learning gains, practices, and attitudes from use of animated ranking tasks focusing on lunar phases will also be included.

This material is based upon work supported by the National Science Foundation under Grant No. 0715517, a CCLI Phase III Grant for the Collaboration of Astronomy Teaching Scholars (CATS). Any

opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

228.06

Overcoming Common Conceptual and Reasoning Difficulties in Cosmology: A Lecture-Tutorial Approach

Edward E. Prather¹, C. S. Wallace², D. Duncan², Collaboration of Astronomy Teaching Scholars (CATS) ¹Center for Astronomy Education (CAE), Steward Observatory, Univ. of Arizona, ²Dept. of Astrophysical & Planetary Sciences, Univ. of Colorado at Boulder.

3:15 PM - 3:30 PM

Room 608

For the past two years, we have conducted fundamental research into Astro 101 students' conceptual and reasoning difficulties in cosmology. To date, we have analyzed the responses of over 2000 students from institutions across the United States to questions on the Big Bang, the expansion and evolution of the Universe, and the evidence for dark matter. Our findings have informed the development of a new suite of cosmology Lecture-Tutorials designed to increase students' understanding of these common cosmology topics. In this talk, we present our key findings with regard to Astro 101 students' common learning difficulties with studying cosmology and provide evidence showing that the new Lecture-Tutorials help students achieve larger learning gains than lecture alone.

This material is based upon work supported by the National Science Foundation under Grant No. 0833364 and Grant No. 0715517, a CCLI Phase III Grant for the Collaboration of Astronomy Teaching Scholars (CATS). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

229 *Evolution of Galaxies IV* Oral Session *Room 607*

229.01D

Galaxy Evolution over the Last Eight Billion Years

Guangtun Zhu¹, M. R. Blanton¹, D. W. Hogg¹, D. J. Eisenstein², A. L. Coil³, R. J. Cool⁴, J. Moustakas³, K. C. Wong⁵

¹New York University, ²Harvard University, ³University of California, San Diego, ⁴Princeton University, ⁵University of Arizona.

2:00 PM - 2:20 PM

Room 607

We study galaxy evolution over the last eight billion years with large, deep galaxy surveys, PRIMUS, SDSS and DEEP2. Galaxies have changed dramatically over this period of time. The global star formation rate has declined by roughly an order-of-magnitude. Red galaxies have grown substantially in number and mass. Blue galaxies have faded and grown redder as their star formation rate dropped. I demonstrate these evolutionary features with new results from these surveys. I also introduce PRIMUS, the largest faint galaxy survey to date. We have measured ~140,000 robust redshifts to the depths of i (AB) ~ 23 up to z^1 , covering 9.1 square degrees of the sky. I show that with the existing deep multi-wavelength imaging in PRIMUS fields we are able to study the evolution in greater detail and investigate proposed physical mechanisms responsible for the evolution.

229.02D

Compact Symmetric Objects In The VLBA Imaging And Polarimetry Survey: A Study Of Half-pint Radio Galaxies

Steven Tremblay¹, G. B. Taylor¹, J. F. Helmboldt², R. W. Romani³, A. C. S. Readhead⁴, T. J. Pearson⁴ ¹University of New Mexico, ²Naval Research Laboratory, Code 7213, ³Stanford University, ⁴California Institute of Technology.

2:20 PM - 2:40 PM

Room 607

Radio loud active galactic nuclei (AGN) are highly luminous supermassive black hole powered radio sources residing within many galaxies. These can have jet structures as long as millions of parsecs and are the brightest persistent sources in the universe. Although AGN have been studied for many years over the entire electromagnetic spectrum there are still many unanswered questions about the birth and evolution of these powerful objects. An understanding of this process is required in order to fully appreciate the role AGN played in the early universe via feedback to their host galaxies. The high resolution provided by the NRAO's Very Long Baseline Array (VLBA) provides a unique tool, allowing investigation of these structures near the base of the jets.

The VLBA Imaging and Polarimetry Survey (VIPS; Helmboldt et al. 2007) observed and imaged a sample of 1127 sources with a resolution of a few milli-arcseconds utilizing full polarization. A subsequent 153 hours of multi-frequency (5, 8.4 & 15 GHz) full polarization follow-up VLBA observations were performed on a subset of 105 Compact Symmetric Object (CSO) candidates, identified in VIPS, to spectrally and morphologically classify them. CSOs are radio galaxies less than a kiloparsec in extent, and are of interest as they are likely an early stage in the evolution of radio galaxies. Since the hotspots terminate so close to the central engine of the galaxy they also provide a unique way to study this environment, and can be used to test the predictions of unified schemes. Here I will present the results of those follow-up observations and attempt to ascertain what this tells us about the growth of AGN.

229.03D

The SFR-ISM Connection Across Cosmic Time.

Matthew Bothwell¹, R. Kennicutt¹, S. Chapman¹

¹University of Cambridge, United Kingdom.

2:40 PM - 3:00 PM

Room 607

The formation of stars from the interstellar medium (ISM) is one of the primary drivers of galaxy evolution, and obtaining a full characterisation of the processes involved is essential if we are to understand the physics behind the formation of galaxies. Viewing galaxies at high redshift gives us a direct window into the various formation processes, but the importance of a comprehensive understanding of the z~0 Universe cannot be overemphasised as the early stages of galaxy evolution leave telltale footprints in the properties of local galaxies. I present work examining the star formation laws in galaxies at both low and high redshift.

I discuss work conducted on a large sample of local (z~0) star forming galaxies, undertaken in order to characterise the nature of star formation and interstellar medium (ISM) behaviour in the local Universe. I discuss the relationship between the well known 'bi-modality' of galaxy types and its connection with the atomic and molecular hydrogen content in the ISM, and note that there is a characteristic transition in HI fraction coinciding with the bi-modality, but there is no such feature in the molecular gas content. I also discuss the distribution function of star formation in the local Universe, calculated in a manner analogous to the luminosity function, and its implications for galaxy formation scenarios. Looking to high redshift, I present high resolution CO and radio observations of a sample of z~2 ultra-luminous infrared galaxies (ULIRGs). This approach sheds light on the spatial distribution of both

molecular gas and star formation, allowing us to place the systems in the context of a Kennicutt-Schmidt (KS)-style star formation law. We find that SMGs lie significantly above the KS relation, indicating that stars are formed more efficiently in these extreme systems than in other high-z star-forming galaxies.

229.04

The Evolution of Dust in High Redshift Galaxies

Johannes Staguhn¹, E. Dwek², D. J. Benford²

¹Johns Hopkins University & NASA's GSFC, ²NASA's GSFC.

3:00 PM - 3:10 PM

Room 607

Far-infrared and submillimeter observations have revealed the presence of galaxies at redshifts > 3, when the universe was less that \sim 2 Gyr old.

GISMO 2 mm observations provide crucial constraints on the mass of dust in these objects by constraining the mass of cold dust.

Using the model of Dwek & Cherchneff (2010) we present analytical solutions that follow the chemical evolution of these objects.

The models include the evolution of dust produced in SN and AGB stars as well as their destruction by SN blast waves.

The talk will present the results of these models.

Support for this work was provided through NSF grant AST-1020981.

229.05

The Evolution Of The UV Luminosity Function

Pascal Oesch¹, R. J. Bouwens², M. Carollo³, G. D. Illingworth⁴, HUDF09 Team

¹UC Santa Cruz, ETH Zurich, ²UC Santa Cruz, Leiden Observatory, ³ETH Zurich, Switzerland, ⁴UC Santa Cruz.

3:10 PM - 3:20 PM

Room 607

At z>~3, the Lyman break selection has been established as a very efficient and powerful tool for identifying star forming galaxies based on broad-band imaging alone. At lower redshifts (z<~2), however, the Lyman break selection has not been used very extensively so far, mainly due to the lack of high-resolution imaging necessary at observed wavelengths of lambda<~3000A. With the advent of the first WFC3/UVIS observations over the GOODS-South field, however, it became possible to study uniformly selected samples of Lyman break galaxies down to z~1.5. We present three such samples of UVIS-dropout galaxies selected in redshift windows centered at z~1.5, z~1.9, and z~2.5. When complemented by a galaxy sample with photometric redshifts in the range z~0.5-2, this allows us to trace the detailed evolution of the UV luminosity function beyond the peak of the cosmic star-formation rate density. In particular, we consistently find extremely steep faint-end slopes of the UV luminosity functions over the full redshift range z~0.75-3. We put this finding in the context of the global evolution of cosmic star formation from the highest redshift galaxies known today down to the local universe and discuss the implication of our results.

229.06

The Evolution of the Galaxy Mass Functions from z~7 to z~4 Valentino Gonzalez¹, I. Labbe², R. Bouwens¹, G. Illingworth¹ ¹University of California Santa Cruz, ²Carnegie Observatories. 3:20 PM - 3:30 PM

Room 607

The determination of the stellar mass content of very high redshift galaxies is a crucial ingredient for the understanding of their evolution. By combining the new WFC3/IR data over the ERS with the deep IRAC observations from the GOODS program, we are able to estimate the masses of a large, newly acquired, sample of ~400 high redshift (z > 4) sources. We recover the stellar Mass - Luv relation previously observed extending it to fainter limits. This relation appears to be constant from $z \sim 7$ to $z \sim 4$, indicating that galaxies with a given stellar mass have similar specific star formation rates at any given redshift z > 4. Because we determine individual masses we are also able to estimate the scatter in the M-Luv relation, finding it to be quite sizable, ~0.5 dex. This relation in combination with the UV LFs has allowed us to construct completeness corrected stellar mass functions. Even though these MFs have a steep faint end, they seem to be shallower than found in some numerical simulations. The stellar mass densities derived from the MFs are in broad agreement with the values expected from the star formation rate density but important differences remain.

230 AGN, QSO, Blazars IV Oral Session Room 609

230.01

Weak-Line Quasars at High Redshift: Extremely High Accretion Rates or Anemic Broad-Line Regions? Ohad Shemmer¹, B. Trakhtenbrot², S. F. Anderson³, W. N. Brandt⁴, A. M. Diamond-Stanic⁵, X. Fan⁵, P. Lira⁶, H. Netzer², R. M. Plotkin⁷, G. T. Richards⁸, D. P. Schneider⁴, M. A. Strauss⁹ ¹University of North Texas, ²Tel-Aviv University, Israel, ³University of Washington, ⁴The Pennsylvania State University, ⁵University of Arizona, ⁶Universidad de Chile, Chile, ⁷University of Amsterdam, Netherlands, ⁸Drexel University, ⁹Princeton University Observatory. 2:00 PM - 2:10 PM *Room 609* We present *Gemini-North K*-band spectra of two representative members of the class of high-redshift quasars with exceptionally weak rest-frame ultraviolet emission lines (WLQs), SDSS J114153.34+021924.3 at z=3.55 and SDSS J123743.08+630144.9 at z=3.49. In both sources we detect an

unusually weak broad H β line and we place tight upper limits on the strengths of their [O III] lines. Virial, H β -based black-hole mass determinations indicate normalized accretion rates of L/L_{Edd} =0.4 for these sources, which is well within the range observed for typical quasars with similar luminosities and redshifts. We also present high-quality *XMM-Newton* imaging spectroscopy of SDSS

J114153.34+021924.3 and find a hard-X-ray photon index of Γ =1.91^{+0.24}-0.22 which supports the virial L/L_{Edd} determination in this source. Our results suggest that the weakness of the broad-emission lines in WLQs is not a consequence of an extreme continuum-emission source but instead due to abnormal broad-emission line region properties.

230.02

Did Weak-line Quasars Just Begin an Active Phase?

Richard M. Plotkin¹, S. F. Anderson², W. N. Brandt³, A. M. Diamond-Stanic⁴, X. Fan⁴, C. L. MacLeod², S. Markoff¹, D. P. Schneider³, O. Shemmer⁵

¹Univ. of Amsterdam, Netherlands, ²University of Washington, ³Pennsylvania State University, ⁴University of Arizona, ⁵University of North Texas.

2:10 PM - 2:20 PM

Room 609

Active Galactic Nuclei (AGN) are often defined by their prominent emission lines, and rare instances of AGN lacking strong emission features are often explained by the presence of a relativistically boosted radio jet (i.e., as for BL Lac objects). However, the SDSS has discovered a population of ~80 high-redshift (z>2.2) radio-quiet quasars with weak emission lines (WLQs) not predicted by the standard orientation based model. Inclusive AGN selection approaches are now also revealing lower-redshift radio-quiet AGN lacking strong emission lines (around 100 objects to date), which are potential analogs to WLQs. Here, we describe our sample of low-redshift WLQ candidates, and we present follow-up multiwavelength observations for 26 objects. Our conclusion is WLQs likely have intrinsically weak broad emission line regions. Finally, we compare WLQs to accreting stellar mass black holes to explore the possibility that WLQs are in a short-lived evolutionary stage where quasar activity has only recently begun. Studying extreme examples of AGN like WLQs may lead to new insight into the formation of broad emission line regions in AGN. Support for this work was provided by a Netherlands Organization for Scientific Research (NWO) Vidi Fellowship.

230.03D

Properties of Low-mass AGN as They Relate to Unification and Massive AGN Carol E. Hood $^{\rm 1}$

¹UC, Irvine.

2:20 PM - 2:40 PM

Room 609

Current unification models of AGN suggest the observational differences between Type 1 and Type 2 objects are solely due to the orientation angle of the object. Observations have proved consistent with predictions and continue to strengthen the case for unification, however, many are still searching for "true" Type 2 objects, including predictions of their formation due to low luminosity or low accretion rate. Low-mass (< 10⁶ solar masses) AGN provide interesting environments in which these unification models can be studied. We also aim to compare the properties of low-mass AGN with their more massive counterparts to look for structural similarities and differences over a more substantial range of luminosities and accretion rates than previously studied.

We present an in-depth multi-wavelength study of one of the prototypical low-mass AGN, POX 52, investigating the properties of the central engine along with that of the host galaxy. This includes data from the VLA, Spitzer, 2MASS, HST, GALEX, XMM, and Chandra, providing us with one of the most comprehensive looks into low-mass AGN. Unlike the other prototypical low-mass AGN, NGC 4395, POX 52 resides in a dwarf elliptical galaxy, accreting at ≈ 0.35 the Eddington limit.

Additionally, we examine a sample 41 Type 1 and Type 2 objects, including POX 52 and NGC 4395, with the Spitzer IRS and a sub-sample of those with XMM to study the absorption properties of low-mass AGN, to test the validity of unification models in the low-mass regime, and to investigate possible structural differences between objects with low and high mass black holes and accretion rates. We will discuss the IR spectral shape and present emission-line diagnostics for Type 1 and Type 2 AGNs at low masses.

230.04

Orientation Effects in the X-ray Properties of High-z 3CRR Quasars

Belinda J. Wilkes¹, J. Kuraszkiewicz¹, M. Haas², R. Antonucci³, M. Ashby¹, P. Barthel⁴, M. Birkinshaw⁵, R. Chini², G. Fazio¹, C. Lawrence⁶, C. Leipski⁷, P. Ogle⁸, B. Schulz⁹, S. Willner¹, F. Heymann¹⁰, D. Worrall⁵ ¹Harvard-Smithsonian, CfA, ²Astronomisches Institut, Ruhr-University, Germany, ³University of California, ⁴Kapteyn Institute, Netherlands, ⁵University of Bristol, United Kingdom, ⁶NASA-JPL, ⁷MPIA, Germany, ⁸Spitzer Science Center, ⁹IPAC, ¹⁰ESO, Germany.

2:40 PM - 2:50 PM

Room 609

A critical problem in understanding active galaxies is separation of intrinsic physical differences from observed differences due to orientation. Relativistic motion in powerful radio sources produces a significant level of anisotropic emission at all but the lowest frequencies. Obscuration is also anisotropic and strongly frequency-dependent. Combined, these two effects result in complex selection effects for observations in most wavebands, and there are few ways to select a sample that is sufficiently unbiased to test orientation effects as predicted by unification models. Low-frequency radio emission is one way to select an orientation-unbiased sample, albeit limited to the minority of AGN with strong radio emission.

We report X-ray observations of a complete, flux-limited sample of 38 high-redshift 3CRR sources, ~1<z<2 with Chandra (35) and XMM (3): 21 quasars and 17 galaxies. According to unification models, the galaxies are viewed edge-on while the quasars are relatively face-on. The majority of the sources are consistent with Unification: most quasars have soft X-ray hardness ratios, high radio core-dominance and high X-ray to radio luminosity ratios while most galaxies have hard X-ray hardness ratio, lower core dominance and lower luminosity ratios. In addition, 5 galaxies have soft but relatively weak X-ray emission suggesting that they are Compton thick and dominated by scattered AGN X-rays (as in the archetypal, edge-on AGN: NGC 1068). Two quasars have intermediate properties including absorbed X-ray and optical emission, and so are likely transition objects, similar to red quasars, where the viewing angle is probably through the edge of the putative disk/torus.

We discuss the implications of our results for Unification models and the make-up of the AGN populations.

230.05

Classification and Statistical Properties of Radio Galaxies with Extended Morphology at z<0.3 Yen-ting Lin¹, Y. Shen², M. Strauss³, G. Richards⁴, R. Lunnan²

¹*IPMU, The University of Tokyo, Japan, ²Harvard-Smithsonian Center for Astrophysics, ³Princeton University Observatory, ⁴Drexel University.*

2:50 PM - 3:00 PM

Room 609

Extended radio galaxies (RGs) have traditionally been classified into Fanaroff-Riley (FR) I/II types, based on the ratio r of the separation between the brightest regions on either sides of the host galaxy and the total size of the radio source. We examine the distribution of various physical properties as a function of r of 1040 extended RGs at z<0.3. About 2/3 of the RGs are lobe dominated (LD) and 1/3 have prominent jets. If we follow the original definition of the FR types, i.e., a division based solely on r, FR I/II RGs overlap in their host properties. However, the rare, LD sources with r>0.8 and [OIII]5007 luminosity>10⁶ Lsun are markedly different on average from the rest of the RGs, for they are hosted in lower mass galaxies, live in relatively sparse environments, and likely have higher accretion rates onto the supermassive black hole (SMBH). Thus, these high emission line luminosity, high-r LD RGs, and the rest of RGs form a well-defined dichotomy. Motivated by the stark differences in the nuclear emission line properties of the RG subsamples, we suggest that the accretion rate onto the SMBH may play the primary role in creating the different morphologies. At relatively high accretion rates, the accretion system may produce powerful jets that create the "classical double" morphology (roughly the LD sources with r>0.8 and emission lines); at lower accretion rates, the jets from a radiatively inefficient accretion flow generate radio lobes without apparent "hotspots" at the edge (corresponding to the majority of LD sources). At slightly lower accretion rates and in galaxies with dense galactic structure, sources with prominent jets result. It is possible that while the high accretion rate systems could affect sub-Mpc scale environments, the jets from lower accretion rate systems may efficiently suppress activity within the host galaxies.

230.06D

Finding Obscured AGNs and Investigating Their Relationships to the Host Galaxy Stephanie M. LaMassa 1

¹Johns Hopkins Univ.. 3:00 PM - 3:20 PM

Room 609

Compton-thick Active Galactic Nuclei (AGN), accreting supermassive black holes at the centers of galaxies surrounded by absorbing material with a column density ($N_{H} > 10^{24}$ cm⁻²), are common in the local universe. To determine an unbiased estimate of the fraction of heavily obscured AGN and to study their properties, we have analyzed two samples of Seyfert 2 galaxies (local AGN where the line of sight is through the obscuring "torus") selected based on intrinsic AGN flux proxies, which are to first-order unaffected by obscuration: an [OIII]-flux limited sample from the Sloan Digital Sky Survey and a midinfrared selected sample from the original IRAS 12-micron survey. Subsequent 2-10 keV X-ray observations can then indicate the amount of obscuration present as this emission is subject to photoelectric absorption and possibly Compton scattering (for $N_H > 10^{24} \text{ cm}^{-2}$) from the putative torus. Signatures of heavy absorption include X-ray attenuation when normalized by intrinsic AGN flux, including infrared parameters derived from detailed Spitzer spectral analysis, and large equivalent width (EW) of the neutral Fe K-alpha line at 6.4 keV. Our results indicate that the majority of these samples evidence heavy absorption, with a continuum of values rather than a segregation into Compton-thin and Compton-thick sub-populations, and that the fitted column density from X-ray modeling can severely under-represent the attenuation implied by these obscuration diagnostics. We find that no statistically significant trends exists between obscuration and host galaxy properties calculated from optical and Spitzer data, suggesting that Compton-thick AGN do not inhabit unique host galaxies from less obscured type 2 Seyferts. Using a sample of 300 star-forming galaxies, we are also exploring the relationship between AGN, star-forming galaxies and composite systems using infrared and optical diagnostics.

230.07

The Extended Radio, Optical And X-ray Emission In MOJAVE Blazars: 0106+013 And 1641+399 Preeti Kharb¹, M. Lister², H. Marshall³, B. Hogan²

¹Rochester Institute of Technology, ²Purdue University, ³MIT.

3:20 PM - 3:30 PM

Room 609

We present the results from our study of the 1.4 GHz radio emission in the kpc-scale lobes of 135 quasars and BL Lac objects belonging to the complete flux-density limited MOJAVE sample. We find that a substantial fraction of BL Lac objects display extended radio powers and morphologies similar to FRII radio galaxies, while many quasars display extended radio powers that are "intermediate" between FRI and FRII radio galaxies. This challenges the simple Unified Scheme that links BL Lacs to FRI and quasars to FRII radio galaxies. We also find that there is a significant correlation between the extended radio emission and parsec-scale jet speeds: the more radio powerful sources possess faster jets. This indicates

that the 1.4 GHz radio emission is indeed related to jet kinetic power. Our pilot study of a sub-sample of 27 blazars possessing large extended radio powers with the Chandra X-ray telescope has revealed X-ray jets in nearly 80% of them. The high detection rate of X-ray jets in these relatively high redshift blazars provides support to the inverse Compton (over cosmic microwave background photons) beaming model for X-ray emission. In order to explore these ideas further, we have recently acquired deep 70 ksec images of two superluminal quasars belonging to this sub-sample, viz., 0106+013, and 1641+399 (3C 345). New Hubble Space Telescope imaging data have also been acquired for 1641+399. The preliminary findings of this multi-wavelength study will be presented.

This work is supported by NASA grant GO9-0128X.

231 *Cosmology II* Oral Session *Room 401*

231.01

Diffuse Gamma-Ray Background from Star-Forming Galaxies

Brian D. Fields¹, V. Pavlidou², T. Prodanovic³

¹Univ. of Illinois, ²California Institute of Technology, ³Univ. of Novi Sad, Serbia. 2:00 PM - 2:10 PM

Room 401

The origin of the extragalactic gamma-ray background is a pressing cosmological mystery. The *Fermi* Gamma-Ray Space Telescope has recently measured the intensity and spectrum of this background; both are substantially different from previous measurements. We present a novel calculation of the gamma-ray background from normal star-forming galaxies. Contrary to longstanding expectations, we find that numerous but individually faint normal galaxies may comprise the bulk of the *Fermi* signal, rather than rare but intrinsically bright active galaxies. This result has wide-ranging implications, including: the possibility to probe the cosmic star-formation history with gamma rays; the ability to infer the cosmological evolution of cosmic rays and galactic magnetic fields; and an increased likelihood to identify subdominant components from rare sources (e.g., dark matter annihilation).

231.02

Extragalactic Background Light and Gamma-ray Opacity

Rudy Gilmore¹ ¹SISSA/ISAS, Italy. 2:10 PM - 2:20 PM Room 401

Gamma rays traveling across extragalactic distances are attenuated due to electron-positron pair production interactions with the extragalactic background light (EBL). I will present new EBL calculations based on semi-analytic models. These models predict the EBL by using physically-motivated prescriptions for galaxy formation in a WMAP5 cold dark matter cosmology. Dust reemission of starlight in the mid- and far-IR is included using templates based on Spitzer data. Our latest models are successful in reproducing a large variety of observational constraints such as number counts, mass functions, and evolving luminosity functions at a wide range of wavelengths. Observations of blazars and gamma-ray bursts at GeV and TeV energies can be used to set limits on the background light, and therefore constrain models of structure formation. I will show a comparison of our model with recent limits from gamma-ray telescopes.

This work has been supported by a Fermi Guest Investigator Grant, and by SISSA/ISAS.

231.03

Feedback from X-rays and Hard Ionizing Radiation from the First Galaxies Aparna Venkatesan¹, A. J. Benson²

¹Univ. of San Francisco, ²California Institute of Technology.

2:20 PM - 2:30 PM

Room 401

The thermal and ionization history of the intergalactic medium (IGM) strongly affects the visibility of distant galaxies, and interactions with the microwave background. We investigate the joint effects of X-rays and helium-ionizing radiation from the first galaxies and quasars on the topology of reionization in the IGM and its heating history, using the recently updated code GALFORM. X-rays have greater penetrating power relative to UV radiation, and in principle could alter the thermal and ionization balance in the IGM significantly. We find that X-rays may not play a dominant role in high-redshift ionization, contrary to theoretical expectations, and that for sufficiently hard first-light sources, the hydrogen and helium I-fronts could track each other closely. We present the observational signatures from X-ray and hard UV ionization, and ways to distinguish them, particularly through their radio signals.

231.04D

The Integrated Light from Galaxies at 1-2 microns Ryan Keenan¹

¹University of Wisconsin, Madison. 2:30 PM - 2:50 PM

Room 401

In Keenan et al. (2010), we present a current best estimate of the integrated near-infrared (NIR) extragalactic background light (EBL) attributable to resolved galaxies in J, H, and Ks. Our new limits to the NIR EBL are in basic agreement with, but 10-20% higher than previous estimates, bringing them into better agreement with estimates of the total NIR EBL (resolved + unresolved sources) obtained from TeV gamma-ray opacity measurements and recent direct measurements of the total NIR EBL, as well as recent integrated galaxy light models. We derive these new limits by combining our deep wide-field NIR photometry from five widely separated fields with other studies from the literature to create a galaxy counts sample that is highly complete and has good counting statistics out to JHKs ~ 28. As part of this effort we present new ultradeep Ks-band galaxy counts from 22 hours of observations with the Multi Object Infrared Camera and Spectrograph (MOIRCS) instrument on the Subaru Telescope. We use this MOIRCS Ks mosaic to estimate the total missing flux from sources beyond our detection limits. We examine field to field variations in our photometry to show that the integrated light from galaxies is isotropic to within uncertainties, consistent with the expected large-scale isotropy of the EBL.

231.05D

Fast and Accurate Primordial Hydrogen Recombination Theory Yacine Ali-Haimoud¹

¹California Institute of Technology.

2:50 PM - 3:10 PM

Room 401

Cosmological hydrogen recombination has recently been the subject of renewed attention because of its importance for predicting the power spectrum of cosmic microwave background anisotropies. Correctly interpreting the upcoming data from the Planck satellite in terms of cosmological parameters indeed requires sub-percent accuracy in theoretical recombination histories. Two aspects are crucial to reach such an accuracy. At early times (z >~800), the dynamics of hydrogen recombination is controlled by the slow decays from the n=2 shell to the ground state, through two-photon decays

from the 2s state and the highly self-absorbed Lyman alpha transition. Subtle radiative transfer effects must be accounted for in order to correctly calculate the rate of decays to the ground state of hydrogen. At late times, due to the decreasing abundance of free electrons and protons, an accurate recombination history must account for all the recombination pathways, and include excited states of hydrogen up to a very high principal quantum number n > 100. The cold radiation field at late times is not strong enough to maintain the angular momentum substates in statistical equilibrium, and they must therefore be followed separately. The traditional method of solution for the multi-level atom is very time consuming computationally and unpractical for inclusion in fast Markov chains for cosmological parameter estimation. In this talk I will present my recent work on a new method of solution, which allows to account for an arbitrarily large number of excited states, and is 5 to 6 orders of magnitude faster than the previously used method. I will also expose my recent work on radiative transfer effects and my current work on a fast and highly accurate recombination code.

231.06

Infrared Background Fluctuations From HST/WFC3

Timothy Dolch¹, H. C. Ferguson², A. M. Koekemoer², T. Sukhbold³, R. Chary⁴, A. Cooray⁵, S. Ravindranath⁶ ¹Johns Hopkins Univ., ²Space Telescope Science Institute, ³University of Arizona, ⁴California Institute of Technology, ⁵University of California, Irvine, ⁶Inter-University Center for Astronomy and Astrophysics, India.

3:10 PM - 3:20 PM

Room 401

The sum total of the energy released by the earliest era of star formation should show up today within the diffuse extragalactic background light (EBL), its signature peaking in the near-infrared. There is considerable controversy over estimates of the average EBL per steradian at wavelengths longward of 1 micron, over measurements of background fluctuations, and over the interpretation of the measurements. Resolving this controversy is important because the fluctuations in the near-infrared may very well contain important information about population III stars and the earliest era of star formation. We present an analysis of background fluctuations in observations of the Hubble Ultra Deep field and the GOODS field obtained with the Hubble Space Telescope Wide-Field Camera 3 (WFC3). The fluctuation signal provides a constraint on the slope of galaxy counts fainter than the levels of individual detection. The color dependence of the fluctuations provides a constraint on the redshift distribution of these very faint sources. In order to analyze the fluctuations, we use both Fourier and P(D) analyses, giving particular attention to systematic sources of error in WFC3. The feasibility of detecting these sources below the detection level in the forthcoming CANDELS survey will also be discussed.

231.07

Einstein's Foil & the Emergence of Structure David F. Bartlett¹

¹Univ. of Colorado. 3:20 PM - 3:30 PM

Room 401

Before introducing his cosmological constant, Einstein considered a difficulty with Newtonian theory: a steady-state, infinite Newtonian stellar system cannot exist at all. He continues: "It seems hardly possible to surmount these difficulties on the basis of Newtonian theory. We may ask ourselves the question whether they can be removed by a modification of the Newtonian theory. First of all we will indicate a method which does not in itself claim to be taken seriously; it merely serves as a foil for what is to follow. In place of Poisson's equation we write $\Delta \varphi - \lambda \varphi = 4 \pi \kappa \rho$

where κ denotes a universal constant. If ρ be the uniform density of a distribution of mass, then ϕ =-4 π κ p/ λ is a solution." Einstein discarded this foil because it is not compatible with his famed equation for general relativity.

In 2004 I proposed a graviton of imaginary mass and a photon of real mass, both equal to 10⁻²⁵ eV. Classically this graviton satisfies Einstein's first equation with an empirical value of $2 \pi/V - \lambda = R_0/20 = 400$ pc. I now suggest an equivalent absolute value $-\lambda = (1/2)E_H^4 2 \pi$ G. where E_H is the Hartree energy 2 × 13.6 eV and c=(h/2\pi) = 1. I will show why this choice and Einstein's second equation gives an emergence of structure at a lookback Z=5.65 dex, a time between nucleosynthesis and recombination when the universe was a plasma of photons, protons, electrons, and helium nuclei. The particular strong structure that I approximate is shown in Hartnett and Hirano (2008). The talk is 3 slides. There will be time for questions.

References- "Analogies between electricity and gravity", Metrologia 41(2004)S115-S124. books: Laughlin (2005), Feynman(1995), Weinberg (1977), Lorentz, Einstein, Minkowski, and Weyl (English) (1923).

232 *Stellar Winds, Jets, and Ejecta* Oral Session *Room 4C-2*

232.01

Sage Studies Of The Mass Return From AGB And RSG Stars In The Large Magellanic Cloud Benjamin A. Sargent¹, S. Srinivasan², M. Meixner¹

¹Space Telescope Science Institute, ²Institut d'Astrophysique de Paris, France.

2:00 PM - 2:10 PM

Room 4C-2

The Surveying the Agents of a Galaxy's Evolution (SAGE; PI: M. Meixner) Spitzer Space Telescope Legacy project aims to further our understanding of the life cycle of matter in galaxies by studying this life cycle in our neighboring galaxy, the Large Magellanic Cloud (LMC). Combining SAGE mid-infrared photometry with that at shorter wavelengths from other catalogs, the spectral energy distribution (SED) for each of >25000 Asymptotic Giant Branch (AGB) and Red Supergiant (RSG) stars in the LMC has been assembled. To model mass loss from these stars, my colleagues and I have constructed the grid of RSG and AGB models (GRAMS) using the radiative transfer code 2Dust. I will discuss how GRAMS was constructed, and how we use it to determine the mass-loss rate for each evolved star studied, which gives the total mass-loss return to the LMC from AGB and RSG stars. In my talk, I show how this total mass-loss return is divided into oxygen-rich (O-rich) and carbon-rich (C-rich) dust using SED-fitting to identify O-rich versus C-rich AGB stars. Applications of this work to determining the mass return from evolved stars in other galaxies, including the Milky Way, will also be discussed.

232.02D

Multiple Spiral Branches On Late AGB Stars

Qian Wang¹, L. M. Willson¹

¹Iowa State Univ..

2:10 PM - 2:30 PM

Room 4C-2

We present some 1-D hydrodynamical models that are capable of generating ring structures around evolved stars. In these models, the pulsation of the star is considered. It initiates the flow and generates shock waves from a static atmosphere. A secondary period is introduced by an orbiting low mass companion. It creates a series of shocks with different strength. The most energetic one collects all the weak shocks forming super shocks around the star. The most interesting results are period coupling

between pulsation period and orbiting period and multiple spiral arms in the far zone (>100AU). In the near zone (~100AU), the strong shocks greatly alter the density and temperature structure. This study enriches the possible mechanisms for the morphology of proto-planetary nebulae. This research is supported by NSF grant 0708143.

232.03

Hybrid Magnetised Winds of AGB Stars - A Fresh Perspective

Anand Thirumalai¹, J. S. Heyl¹

¹University of British Columbia, Canada.

2:30 PM - 2:40 PM

Room 4C-2

We present calculations for a magnetised hybrid wind model for Asymptotic Giant Branch (AGB) stars. The model incorporates a canonical Weber-Davis (WD) stellar wind with dust grains in the envelope of an AGB star. The resulting hybrid picture preserves traits of both types of winds. It is seen that this combination requires that the dust-parameter be less than unity in order to achieve an outflow. The emergence of critical points in the wind changes the nature of the dust-driven outflow, simultaneously, the presence of a dust condensation radius changes the morphology of the magnetohydrodynamic (MHD) solutions for the wind. In this context, we additionally investigate the effect of having magnetic-cold spots on the equator of an AGB star and its implications for dust formation; which are seen to be consistent with previous findings.

This research was supported by funding from NSERC.

232.04D

Exploring And Modeling High-excitation Emission In The Ejecta And Wind Of Eta Carinae Andrea ${\sf Mehner}^1$

¹University of Minnesota.

2:40 PM - 3:00 PM

Room 4C-2

Eta Car is the most massive, most luminous star in our region of the Galaxy. In the 1840's its unstable nature culminated in the "Great Eruption" when it briefly became the second brightest star in the sky and ejected several solar masses, which we today see as a bipolar nebula enshrouding the surviving star. Eta Car's ejecta show some of the most complex and demanding spectra of any astronomical object. Combining the vast amount of data from the HST/STIS, Gemini/GMOS, and VLT/UVES instruments during 1998 to 2010, I analyzed and compared several "spectroscopic cycles" in the entire optical spectrum. A variety of different slit position angles make it possible to map the emission across the nebula. The complex outer ejecta of eta Car make it also possible to observe the star at different stellar latitudes via reflected light. Results include:

1) An analysis of the high-excitation emission lines that are indicators of eta Car's spectroscopic events; every 5.54 years, they abruptly disappear for a few weeks. They also provide clues to the far-UV output of the presumed secondary star. I use ionizing fluxes of model atmospheres and the photoionization code Cloudy to define a parameter space for the secondary star.

2) Analysis and modeling of He I, He II, and N II lines to better understand the origin and physics of the events.

3) Recent dramatic changes in the wind of eta Car suggest a rapid decrease in the wind density.

232.05 Low Mass Star L1551 IRS 5 Jets Leung Ka Wing¹, J. Lim¹

¹The University of Hong Kong, Hong Kong. 3:00 PM - 3:10 PM Room 4C-2

L1551 IRS5 is a multiple protostellar system showing two nearly parallel jets of ionized gas. The southern jet shows a peculiar bend at about 0.6 [[Unsupported Character - ̋]] to the southwest of its driving source. One hypothesis to explain the bend jet is interaction of the two jets. In order to test the hypothesis, we compared the maps of the jet in 3 different epochs comprising 1994, 2002 and 2003. The 3.5cm continuum maps observed by Very Large Array with the Pie Town antenna reveal the intensity of the Southwest part of the southern jet increase from 1994 to 2002. Comparing epoch 2002 to 2003, the southwest part of the Southern jet keeps changing in intensity. Furthermore, an intensity change is found close to or at the location where jet bends. We don't see change anywhere even close to the source where the emission is strongest and any change easiest to detect. The position of the bending jet shows an increase in intensity, but the spatial position is the same. We are looking at different models for what could cause the observed changes.

232.06D

X-rays from Planetary Nebulae: Unveiling Binarity and Wind Collisions

Rodolfo Montez, Jr.¹

¹*Rochester Institute of Technology.*

3:10 PM - 3:30 PM

Room 4C-2

Planetary nebulae (PNe), the ionized, ejected envelopes of low- to intermediate-mass stars, are thought to be shaped by a nascent fast wind from the spent core (a future white dwarf) that collides with and sweeps up previously ejected material (red and asymptotic branch giant winds). This collision can generate an X-ray emitting "hot bubble" that fills the swept-up cavity. Circumstellar material in a dense torus or disk, likely due to an interacting binary in the PN nucleus, is widely believed to collimate the winds that shape non-spherical PNe. Hence, PNe offer excellent opportunities to study astrophysical shocks and binary interactions. In my thesis, I address these topics via a comprehensive analysis of new and archival (pointed and serendipitous) X-ray observations performed by Chandra and XMM-Newton Xray satellite observatories. This analysis yields new information on the X-ray characteristics (detections and non-detections) of over 50 PNe (~35% of which were detected). Based on spatial/spectral analysis of a dozen diffuse X-ray emitting PNe, I confirm that hot bubble temperatures are generally much lower than predicted by simple shock models given measured central star fast wind velocities. Comparison of the X-ray emission and central star properties of the sample PNe with the predictions of heat conduction models indicates that some hot bubbles are regulated by heat conduction, while others appear to require alternative temperature-regulating mechanisms. From new detections of point-like hard X-ray emission from the binary star nuclei of LoTr5, DS1, and HFG1, I demonstrate that the X-ray emission most likely arises from rejuvenated coronae around the spun-up companions in these systems. These results place constraints on putative spun-up binary companions within other PNe in which pointlike central sources have gone undetected by XMM and/or Chandra. I conclude with suggestions as to the most promising directions for future X-ray observations of PNe.

233 *Evolution of Galaxies V* Oral Session *Room 4C-3*

233.01D

A Quantitative Analysis of Star-Forming Galaxies at Intermediate Redshifts: Number Counts, Morphological Sequences, and Evolutionary Timescales Elysse Voyer¹

¹*CUA/NASA's GSFC.* 2:00 PM - 2:20 PM

Room 4C-3

We present a multiwavelength study of rest-frame far-ultraviolet (FUV) selected galaxies at intermediate redshifts (0.1 < z < 1) in the GOODS-N & -S fields. The HST data analyzed were taken with ACS, WFPC2, and WFC3 spanning from FUV to near-infrared bands. The galaxy sample is analyzed in bins of specified time to facilitate comparisons with predictions from theory and simulations of timescales for merger events and morphological transformation in secular evolution scenarios. Quantitative rest-frame i-band morphologies from GALFIT are compared with SED based spectral types revealing trends between morphology and star-formation at intermediate redshifts. Sizes of star-forming clumps are also measured in the rest-frame FUV data for different morphologies to test for size evolution which could be an indication of disk or bulge build-up. We compare morphologies of the star-forming sample to those of a large non-FUV selected galaxy sample in the GOODS-N & -S fields over the same redshift ranges to pinpoint significant morphological differences. We also compare with a local sample obtained from the Sloan Digital Sky Survey representing the local Hubble sequence. The FUV sample is used to measure faint end number counts and the resolved background contribution, covering a larger area (15.9 square arcmin.) than previously observed at these wavelengths (1614Å) and magnitudes (20.5-29.5). Our results are in good agreement with recent semi-analytical models based on dark matter "merger trees" (Somerville et al. 2008, Gilmore et al. 2009) and suggest that other HST studies using smaller detection areas have over-predicted the number counts.

233.02D

Star Formation And Environment Of Galaxies In The Nearby Universe Smriti Mahajan $^{\rm 1}$

¹*Harvard-Smithsonian Center for Astrophysics.* 2:20 PM - 2:40 PM

Room 4C-3

My Ph.D. research focuses on the role of star formation in galaxies. Star formation, a critical driver of galaxy evolution, responds both to external influences (local and global environment) and internal influences (e.g., dust). I show how common observables, in particular the star formation rate (SFR), is influenced when galaxies fall into clusters via large-scale filaments. I find that complex galaxy populations (e.g., blue passive galaxies) are a direct consequence of the impact of environment on the star formation of galaxies. For a sample of nearby ($z^{-0.1}$) clusters I show that star formation in galaxies falling into clusters seems to be enhanced on the clusters' periphery. I argue that galaxy-galaxy evolution. I use the line-of-sight velocity information obtained from the integrated galaxy spectra together with dark matter simulations to show that statistically, a single passage through the cluster core reduces the SFR in a galaxy by 40%. Using the nearby (100 Mpc) Coma supercluster, I show that the star formation varies with galaxy type: while dwarfs are star-forming everywhere except

in the core of clusters and groups, their massive counterparts are mostly evolving passively. Transitional populations (i.e., post-starburst or k+A galaxies) preferentially lie in the vicinity of richer structures. I also present the first results from the Star Formation Reference Survey (SFRS), where I compare global SFR metrics for a FIR-selected sample of star-forming galaxies in the nearby Universe obtained from the ultra-violet, mid- and far-infrared to 1.4 GHz radio imaging to show how the SFRs based on these canonical indicators correlate with the total SFR expected from a galaxy's bolometric luminosity.

233.03D

An Accurate New Technique for Determining Star Formation and AGN Fractions in Optical Spectra James T. Allen¹, P. C. Hewett¹, J. Baldwin², G. Ferland³

¹University of Cambridge, United Kingdom, ²Michigan State University, ³University of Kentucky. 2:40 PM - 3:00 PM

Room 4C-3

The observed phenomena of star formation (SF) and active galactic nuclei (AGN) have long been thought to be intimately linked, but to date the details of their connection have remained elusive. In recent years the Sloan Digital Sky Survey (SDSS) has provided very large samples of high quality galaxy spectra, allowing progress to be made in statistical analyses of the AGN/SF link. However, such analyses currently rely on measurements of particular emission line ratios and the Baldwin, Phillips & Terlevich (BPT) diagrams to classify objects as SF-dominated, AGN-dominated, or "composite". Such classifications do not produce complete samples of objects with SF or AGN, and are not sensitive to the low-level activity that may shed important light on the relationship between the different sources.

I will present a new technique, based on mean field independent component analysis, which allows the fractional contribution of AGN and SF to each object to be quantified. In doing so, we can classify objects based on direct measurements of their compositions, rather than the indirect BPT-based methods. We are able to disentangle the AGN and SF contributions to the "composite" region, that encompasses a large number of the objects observed by the SDSS. Additionally, low-level SF can be identified in AGN-dominated galaxies, and low-level AGN in SF-dominated galaxies. The technique can be applied to all galaxy spectra in the SDSS with the required spectral coverage, and readily extended to encompass other spectroscopic surveys. Together, these developments allow a new level of precision in the study of the link between AGN and SF.

JTA acknowledges the support of an STFC PhD studentship.

233.04

Panchromatic Estimation of Star Formation Rates in BzK Galaxies.

Peter Kurczynski¹, E. Gawiser¹, M. Huynh², R. J. Ivison³, E. Treister⁴, I. Smail⁵, G. A. Blanc⁶, C. N. Cardamone⁷, T. R. Greve⁸, E. Schinnerer⁸, M. Urry⁹, P. van der Werf¹⁰, F. Walter⁸ ¹*Rutgers University,* ²*California Institute of Technology,* ³*UK ATC; Royal Observatory, United Kingdom,* ⁴*University of Hawaii,* ⁵*Durham University, United Kingdom,* ⁶*University of Texas,* ⁷*MIT,* ⁸*MPI for Astronomy, Germany,* ⁹*Yale University,* ¹⁰*Leiden University, Netherlands.*

3:00 PM - 3:10 PM

Room 4C-3

We determine Star Formation Rates (SFRs) in a sample of color selected, star forming (sBzK) galaxies (K_{AB}<21.8) in the Extended Chandra Deep Field - South (ECDF-S). To avoid AGN, we eliminate 12 percent of the original sample that have X-ray detections in Chandra catalogs. X-ray stacking, including in the 4 Ms CDF-S, shows that the remaining 597 sBzK galaxies are not dominated by obscured AGN. Galaxies are separated into bins of photometric redshift; average flux densities are measured with stacking analyses in Chandra (0.5-8 keV), Spitzer-MIPS (24, 70 micron), sub-millimeter (250, 350, 500 micron from BLAST, 870 micron from LESS), and radio (VLA 1.4 GHz and GMRT 610 MHz) data. We include averages of
aperture fluxes in MUSYC UBVRIz'JHK images to determine UV-through-radio Spectral Energy Distributions (SEDs). We estimate SFR from SED fits to determine the total IR luminosity, and we compare SFR calibrations from X-ray, UV, 24 micron, FIR and radio wavebands. We compare radio and Xray SFR calibrations to each other, and we find preferred calibrations for each waveband. We find consistency with our best estimator, SFR_{IR+UV}, to within a factor of two for dust corrected UV and the preferred radio SFR calibration. Our results show that 24 micron-only and X-ray SFR estimates should be used with caution. We gratefully acknowledge support from the National Science Foundation and NASA via an archival Spitzer grant.

233.05

Estimating the Star Formation History of the Local Volume from Resolved Stellar Populations

Benjamin F. Williams¹, J. J. Dalcanton¹, L. C. Johnson¹, D. Weisz¹, A. Dolphin², A. Seth³, K. Gilbert¹, E. Skillman⁴

¹Univ. of Washington, ²Raytheon, ³Center for Astrophysics, ⁴Univ. of Minnesota.

3:10 PM - 3:20 PM

Room 4C-3

We present a measurement of the age distribution of stars residing in nearby spiral disks and dwarf galaxies. With these measurements, we estimate a complete star formation history of the $\sim 140 \text{ Mpc}^3$ covered by the volume-limited sample of galaxies in the Advanced Camera for Surveys (ACS) Nearby Galaxy Survey Treasury (ANGST). Our sample allows us to separate the contributions by galaxy type. The total star formation rate density history is dominated by the large spirals in the volume, although the sample consists mainly of dwarf galaxies. In all galaxy types, our measurement shows a factor of ~ 3 drop in star formation rate density at $z\sim 2$, in approximate agreement with results from other measurement techniques. Differences in the detailed results of our analysis and those of redshift surveys will be discussed. ANGST is supported by HST GO-10915 administered by NASA.

233.06

The Star Formation Rate-Density Relation at 0.6<z<0.9 and the Role of Star Forming Galaxies Shannon Patel¹, D. D. Kelson², B. P. Holden³, G. D. Illingworth³, M. Franx¹

¹Leiden University, Netherlands, ²Carnegie Observatories, ³University of California, Santa Cruz. 3:20 PM - 3:30 PM

Room 4C-3

We study the star formation rates (SFRs) of galaxies as a function of local galaxy density at 0.6<z<0.9. We used a low-dispersion prism in IMACS on the 6.5 m Baade (Magellan I) telescope to obtain spectra and measured redshifts to a precision of sigma $_z/(1+z)^{-1\%}$ for galaxies with z<23.3 AB mag. We utilized a stellar mass-limited sample of ~1000 galaxies above M=1.8x10¹⁰ Msun to conduct our analysis. With SFRs measured from (1) Spitzer MIPS 24 µm imaging, (2) SED fitting, and (3) [OII] 3727A emission, we find the median specific SFR (SSFR) and SFR to decline with increasing local galaxy density by roughly an order of magnitude, from the low-density field to the cores of groups and a cluster. We find a similar decline even after removing the cluster environment from our sample. Galaxies in clusters and groups at these redshifts therefore have lower overall star formation (SF) activity than galaxies in the field, as is the case at z^{-0} . Using the rest-frame U-V and V-J colors to select star-forming galaxies (SFGs), including both unobscured (i.e., blue) and obscured (i.e., red), we find the SSFRs of SFGs to decline with increasing density by factors of ~2-5 depending on the SFR indicator. The declining SFRs of SFGs with density is paralleled by a decline in the median A_v, providing indirect evidence that the cold gas that fuels future SF is being removed from galaxies in higher density environments. The order of magnitude decline in the SSFR-density relation at 0.6<z<0.9 is therefore driven by a combination of declining SFRs of SFGs as well as a changing mix of SFGs and quiescent galaxies.

234 *Pulsars, Neutron Stars II* Oral Session *Room 4C-4*

234.01

Finding Pulsars with Einstein@Home

Benjamin Knispel¹, B. Allen¹, J. Cordes², J. Deneva³, D. Anderson⁴, C. Aulbert¹, N. D. R. Bhat⁵, O. Bock¹, S. Bogdanov⁶, A. Brazier², F. Camilo⁷, D. J. Champion⁸, S. Chatterjee², F. Crawford⁹, P. B. Demorest¹⁰, H. Fehrmann¹, P. C. C. Freire⁸, M. E. Gonzalez¹¹, D. Hammer¹², J. W. T. Hessels¹³, F. A. Jenet¹⁴, L. Kasian¹¹, V. M. Kaspi⁶, M. Kramer⁸, P. Lazarus⁶, J. van Leeuwen¹³, D. R. Lorimer¹⁵, A. G. Lyne¹⁶, B. Machenschalk¹, M. A. McLaughlin¹⁵, C. Messenger¹, D. J. Nice¹⁷, M. A. Papa¹, H. J. Pletsch¹, R. Prix¹, S. M. Ransom¹⁰, X. Siemens¹², I. H. Stairs¹¹, B. W. Stappers¹⁶, K. Stovall¹⁴, A. Venkataraman³, G. Desvignes⁴ ¹Albert Einstein Institute Hannover, Germany, ²Cornell University, ³Arecibo Observatory, ⁴University of *California at Berkeley*, ⁵Swinburne University, Australia, ⁶McGill University, Canada, ⁷Columbia University, ⁸Max Planck Institute for Radioastronomy, Germany, ⁹Franklin and Marshall College, ¹⁰NRAO, ¹¹University of British Columbia, Canada, ¹²University of Wisconsin - Milwaukee, ¹³University of Amsterdam, Netherlands, ¹⁴University of Texas - Brownsville, ¹⁵West Virginia University, ¹⁶University of Manchester, United Kingdom, ¹⁷Lafayette College.

2:00 PM - 2:10 PM

Room 4C-4

The Einstein@Home project is a global distributed computing project and aggregates the computer power of hundreds of thousands of volunteers from 192 countries to "mine" large data sets. Its long-term goal is the detection of continuous gravitational waves in data from the LIGO interferometric gravitational wave detectors. Since March 2009 about a third of Einstein@Home's computation cycles is also used to search for tight binary pulsars in PALFA radio data from the Arecibo observatory. In July 2010, two new pulsars were found by Einstein@Home, J2007+2722 and J1952+26, the latter in a binary system with 9.4 hours orbital period. Here, we present an overview of the status of the Einstein@Home project and describe its search for radio pulsars in binaries with periods larger than 11 minutes. Further, we briefly review Einstein@Home's pulsar discoveries.

234.02D

MUFFINS: Metallurgy Uncovers Forced Fractures Inside Neutron Stars

Kelsey L. Hoffman¹, J. S. Heyl¹

¹Univ. of British Columbia, Canada.

2:10 PM - 2:30 PM

Room 4C-4

As a result of nuclear reactions within the neutron star crust, even neutron stars that have not accreted matter can have impurities in their crust. These impurities would have an effect on the mechanical properties of the crust, possibly creating a more brittle structure. In order to investigate the properties of an impure crust we are performing molecular dynamic simulations using the Large scale Atomic/Molecular Massively Parallel Simulator (LAMMPS). The simulations are run at fixed energy and volume with the isotopes interacting via a repulsive Yukawa potential. Here we present effects of impurities with respect the the breaking strain in a non-accreting neutron star crust.

234.03D

Multidimensional Simulations of Convection Preceding Type I X-ray Bursts Christopher M. Malone¹, A. S. Almgren², J. B. Bell², A. J. Nonaka², M. Zingale¹ ¹Stony Brook University, ²CCSE at Lawrence Berkeley National Laboratory.

2:30 PM - 2:50 PM

Room 4C-4

Type I X-ray bursts are interesting thermonuclear phenomena that can be used to determine the mass and radius of the underlying neutron star and hence help constrain the equation of state for dense matter. Particularly important is our physical understanding of how a localized, subsonic burning front ignites and spreads, the state of the material in which the burning front propagates, and the extent to which heat released from reactions expands the photosphere of the neutron star. Multidimensional simulation of low Mach number astrophysical flows, such as the propagation of a flame or the slow convective turnover, in such systems have been rather restricted in the past; fully compressible hydrodynamics algorithms have a timestep size that is constrained by the propagation of acoustic waves, which can be neglected in low Mach number flows of this type. Here we present results of multidimensional, plane-parallel simulations of the convection preceding ignition in a Type I X-ray burst. We use a low Mach number code, MAESTRO, based on a low Mach number approximation, which filters acoustic waves from the system allowing for a larger timestep size while retaining the important compressible features, such as expansion from local heating and composition change. This allows us to perform long-term evolution of the system and characterize the effects of convection on the atmosphere. In particular, we find that the convection dredges up some of the underlying ⁵⁶Fe neutron star material into the atmosphere, which may affect any subsequent subsonic burning front. This work is supported under the DOE/Office of Nuclear Physics, grant No. DE-FG02-06ER41448 (Stony Brook) and by the SciDAC Program of the DOE Office of Mathematics, Information, and computational Sciences

under the DOE under contract No. DE-AC02-05CH11231.

234.04D

Finite Range Thomas Fermi Model : Modified model

Yeunhwan Lim¹, J. M. Lattimer¹

¹SUNY Stony Brook. 2:50 PM - 3:10 PM

Room 4C-4

We extended the truncated Finite Range Thomas Fermi model (FRTF hereafter).

Adding an additional density-dependent interaction, we could adjust the nuclear incompressibility from 316MeV to 235MeV and also fit the properties of pure neutron matter near the saturation density. The new interaction is used to compute semi-infinite surface properties as well as properties of finite nuclei including the neutron skin thickness.

Compared to the truncated model, we obtain a lower critical temperature for bulk matter coexistence as well as a lower maximum neutron star mass.

Using the Wigner-Seitz approximation as in the truncated model, we construct the equation of state of hot dense matter. The spherical Wigner-Seitz approximation is extended to ellipsoidal, cylindrical and planar geometries to model deformed nuclei and pasta phases at subnuclear densities.

We compare the composition of the neutron star crust to previously published results.

Two Pulsar Discoveries from the Einstein@Home Distributed Computing Project

Julia S. Deneva¹, B. Knispel², B. Allen², J. Cordes³, S. Bogdanov⁴, A. Brazier³, R. Bhat⁵, F. Camilo⁶, S. Chatterjee³, F. Crawford⁷, G. Desvignes⁸, P. Freire⁹, J. Hessels¹⁰, F. Jenet¹¹, V. Kaspi⁴, M. Kramer⁹, P. Lazarus⁴, D. Lorimer¹², J. van Leeuwen¹³, A. Lyne¹⁴, M. McLaughlin¹², D. Nice¹⁵, S. Ransom¹⁶, X. Siemens¹⁷, I. Stairs¹⁸, B. Stappers¹⁴, K. Stovall¹¹

¹Arecibo Observatory, ²Max Planck Institute for Gravitational Physics, Germany, ³Cornell University, ⁴McGill University, Canada, ⁵Swinburne University, Australia, ⁶Columbia University, ⁷Franklin & Marshall College, ⁸UC Berkeley, ⁹Max-Planck-Institut für Radioastronomie, Germany, ¹⁰Astronomical Institute "Anton Pannekoek", Netherlands, ¹¹University of Texas, Brownsville, ¹²West Virginia University, ¹³ASTRON, Netherlands, ¹⁴University of Manchester, United Kingdom, ¹⁵Lafayette College, ¹⁶NRAO, ¹⁷University of Wisconsin, Milwaukee, ¹⁸University of British Columbia, Canada.

3:10 PM - 3:20 PM

Room 4C-4

We present two pulsars discovered by Einstein@Home, a distributed computing project that runs on volunteers' computers and searches for gravitational waves in LIGO data and binary pulsars in Arecibo PALFA data. J2007+27 is an isolated pulsar with a period of 24.49 ms. Its unusually large duty cycle and the presence of emission almost throughout the rotation period suggests that its magnetic and spin axes are nearly aligned. Limits on the period derivative, magnetic field, and age indicate that this is the fastest-spinning disrupted recycled pulsar known to date. J1952+26 has a period of 20.73 ms and is in a 7-hour binary. Assuming a pulsar mass of 1.4 Msun, the system's mass function indicates that the minimum companion mass is 0.95 Msun. The companion is likely a neutron star or a massive white dwarf, which makes the system an excellent candidate for Shapiro delay measurement and therefore an accurate estimate of the pulsar and companion masses.

234.06

Comparisons between Ground-based, Artifical "Pulsars" and Data from the Parkes Multibeam Survey John Singleton¹, A. Schmidt², Z. Wang², Q. Marksteiner², H. Ardavan³, J. Middleditch², P. Sengupta¹ ¹National High Magnetic Field Laboratory, ²LANL, ³University of Cambridge, United Kingdom. 3:20 PM - 3:30 PM

Room 4C-4

In a number of recent papers, we have invoked superluminal (faster than light *in vacuo*) polarization currents as the dominant mechanism for the pulsar emissions that are observable from Earth. Unlike electrons, which possess rest mass and are therefore limited to speeds less than that of light, polarization currents may travel arbitrarily fast, because the displacements of the negative and positive particles that make them up are rather small. We have shown that the characteristic emission from these currents, which are driven by the pulsar's rotating magnetic field, is able to account for the spectra of the Crab and 8 other pulsars over 16-18 orders of magnitude of frequency with a minimum of adjustable parameters. In this presentation, we will review data from ground-based experiments with superluminal polarization currents, in effect, artificial pulsars. These are shown to emit "beams" that sharpen with increasing distance, and whose intensity decreases more slowly with distance than the inverse-square law. A Maximum-Likelihood analysis of data from about 500 pulsars in the Parkes Multi-Beam Survey demonstrates that real pulsars behave in an analogous way, providing very strong support for the superluminal model.

Tuesday, January 11, 2011, 3:40 PM - 4:30 PM 235 *Warner Prize: Millisecond Pulsars: The Gifts that Keep on Giving* Invited Session *Ballroom 6AB*

235.01 Millisecond Pulsars: The Gifts that Keep on Giving Scott M. Ransom¹ ¹NRAO.

Ballroom 6AB

There are about 2000 pulsars known, and while all of them as neutron stars are fascinating objects, the best and most exciting science comes from a very small percentage (~1%) of exotic objects, most of which are millisecond pulsars (MSPs). These systems are notoriously hard to detect, yet their numbers have bloomed in the past 5-6 years via surveys using the world's largest radio telescopes and the Fermi Gamma-ray Space Telescope. Timing observations of these new MSPs as well as much improved monitoring of previously known MSPs are providing a wealth of science. In this talk I'll briefly cover 3 main areas in basic physics where systems like these are making an impact: strong-field tests of general relativity, the nature of matter at supra-nuclear densities, and the direct detection of gravitational waves (e.g. NANOGrav). In addition, several of the systems exhibit some very interesting astrophysics as well, including a transition from X-ray binary to MSP and a likely triple system that turned into an eccentric MSP binary.

Tuesday, January 11, 2011, 4:30 PM - 5:20 PM

236

A New View of the High Energy Gamma-Ray Sky with the Fermi Gamma-Ray Space Telescope Invited Session Ballroom 6AB

236.01

A New View of the High Energy Gamma-Ray Sky with the Fermi Gamma-Ray Space Telescope Julie E. McEnery¹

¹NASA's GSFC.

Ballroom 6AB

Following its launch in June 2008, high-energy gamma-ray observations by the Fermi Gamma-ray Space Telescope have unveiled over 1000 new

sources and opened an important and previously unexplored window on a wide variety of phenomena. These have included the discovery of an

population of pulsars pulsing only in gamma rays; the detection of photons up to 10s of GeV from gamma-ray bursts, enhancing our

understanding of the astrophysics of these powerful explosions; the detection of hundreds of active galaxies; a measurement of the high

energy cosmic-ray electron spectrum which may imply the presence of nearby astrophysical particle accelerators; the determination of the

diffuse gamma-ray emission with unprecedented accuracy and the constraints on phenomena such as supersymmetric dark-matter

annihilations and exotic relics from the Big Bang. Continuous monitoring of the high-energy gamma-ray sky has uncovered numerous

outbursts from active galaxies and the discovery of transient sources in our galaxy. In this talk I will

describe the current status of the Fermi observatory and review the science highlights from Fermi.

Wednesday, January 12, 2011, 8:30 AM - 9:20 AM

300 *The First Supermassive Black Holes* Invited Session *Ballroom 6AB*

300.01 The First Supermassive Black Holes Mitchell C. Begelman¹

¹Univ. of Colorado. Ballroom 6AB

The supermassive black holes that populate galactic nuclei could have grown from an early population of stars, or via the direct collapse of much larger masses of gas. I will discuss recent investigations of the latter possibility, focusing on the physics that may have regulated early black hole formation and growth. Black hole formation by direct collapse implies the existence of hitherto undetected classes of objects; I will outline the prospects for detecting them.

Wednesday, January 12, 2011, 9:00 AM - 6:30 PM 331

Observing with ALMA Poster Session *Exhibit Hall*

331.01

A Dedicated Effort to Investigate the Formation Chemistry of C3H2O Isomers in the ISM

Amy Robertson¹, A. Remijan², R. Pulliam² ¹NRAO and University of Arizona, ²NRAO.

Exhibit Hall

The astronomical molecular inventory currently stands at ~169 detected species and their corresponding isotopologues. Yet, given this vast molecular inventory, the formation mechanisms of even the simplest molecular species detected in these varied environments are still not well understood. Molecular isomers are also prevalent in astronomical environments and may play a role in determining the formation route of molecules in space. Molecular isomers contain the same atoms yet have different structures. Recently, Lattelais et al. 2009, suggested that the isomer with the lowest zero point bonding energy (ie, the most stable isomer) should be the most abundant, and thus most easily detected in astronomical environments. We explored this theory using the C3H2O isomers. C3H2O forms three structural isomers; propadienione (CH2CCO), propynal (HCCCHO) and cyclopropenone (c-C3H2O), each with increasing bonding energy, respectively. We searched existing broadband spectral line surveys in the ISM and compared that to laboratory spectra and also simulated chemical reactions to form the C3H2O isomers using Gaussian09. All spectral explorations resulted in less then convincing proof of the presence of the two lowest energy isomers in the ISM, yet cyclopropenone is readily detected and confirmed. More observations are needed to solidify conclusions. However, the evidence is building that the lowest energy C3H2O isomers are not present in the ISM. This supports the conclusion that the formation chemistry is more important than relative molecular stability in determining the abundance of molecules in astronomical environments.

The Search for the 6.7 GHz Methanol Maser in Markarian 3

Corinne Fletcher¹, V. Impellizzeri²

¹University of Missouri - Columbia, ²National Radio Astronomy Observatory. Exhibit Hall

The 5_1 --> 6_0 A⁺ transition of methanol at 6.7 GHz is among the strongest galactic masers known, and uniquely traces sites of high-mass star formation. Over 800 of these masers have been detected and studied in our galaxy and three in the Large Magellanic Cloud. Methanol masers are observed spatially near OH and H2O masers. The large number of galactic masers and the existence of luminous extragalactic H2O and OH megamasers have given the motivation to search for 6.7 GHz maser emission in extragalactic sources. Several surveys have been conducted to find extragalactic methanol, using H2O and OH megamaser emission as selection criteria. However, none of the surveys have been successful. In 2008, we conducted a survey with the 100-m Effelsberg telescope in Germany towards a sample of AGN selected for being Compton thick and for having a previous detection of molecular lines. This survey produced a detection of the 6.7 GHz transition in absorption towards NGC 3079 and a tentative detection in emission towards Markarian 3. Markarian 3 was observed again in 2009 with the EVLA to independently confirm the tentative line. We report here the detection of an emission line feature at the systemic velocity of the galaxy. With a line peak of ~ 2 mJy, the emission matches the line observed with Effelsberg within 40 km/s. However, due to the low signal-to-noise of our observations, the detection remains tentative. If real, the line would correspond to an intrinsic maser luminosity of 1.9 L_{solar}. This would be the most luminous methanol maser known with a factor of 10⁶ more luminous than galactic masers. This would open up the exciting possibility of a new class of methanol masers, possibly associated with AGN activity.

331.03

The Effect of Environment on Star Formation in Giant Molecular Clouds in NGC 2403 Ashley Bemis¹, A. Leroy², R. Friesen²

¹University of Massachusetts, Amherst, ²National Radio Astronomy Observatory. Exhibit Hall

Giant Molecular Clouds (GMCs) are believed to be the exclusive sites of star formation. An important step in understanding star formation in GMCs is to study multiple galactic environments. GMCs have been studied extensively in the Milky Way, and clear relationships have been observed between fundamental GMC properties such as size, luminosity, and velocity dispersion. Deriving the same properties from a different galaxy allows us to measure any possible variation in star-formation due to galactic environment differences. Here, we derive these properties for GMCs within the nearby galaxy NGC 2403, allowing us to measure any possible variation in star formation due to differences in galactic environment. NGC 2403 is one of the closest galaxies not located within the Local Group, allowing a detailed view of a distinct environment and the ability to resolve individual GMCs. We study 12COJ=1-0 emission in five star-forming regions to derive the aforementioned GMC properties, and we compare the results to those of GMCs in the Milky Way and other galaxies. In the same regions, we look for correlations of GMC properties with dust abundance and radiation field. Despite a range of dust abundances, we find that the physical properties of GMCs in NGC 2403 do not vary significantly from the fundamental relationships determined for GMCs in the Milky Way. This project was funded by the National Radio Astronomy Observatory and the National Science Foundation.

Emission Line Searches for High-Redshift Galaxies with ALMA

Justin Spilker¹, M. Lacy²

¹Iowa State University, ²National Radio Astronomy Observatory. Exhibit Hall

We present a simulation of a spectral line observation of a field of spiral galaxies at high redshift using the Atacama Large Millimeter/Submillimeter Array(ALMA), obtained by making use of the virtual galaxy catalog developed by Obreschkow et al. as part of the Square Kilometer Array Simulated Skies effort. Our method selects galaxies with high star formation rates and calculates continuum and CII 1900GHz line fluxes for each galaxy before simulating observations in early and full science configurations at 234GHz. Using nine eight-hour observations, we detect both high redshift (z~7.26) objects in our approximately one square arcminute field, indicating that while a large scale survey will be necessary to build up a significant sample of these very distant galaxies, this task is within ALMA's technical capabilities. Such a survey would yield valuable information about the formation and evolution of galaxies and large scale structure in the universe, and also give details of the epoch of the reionization to be computationally feasible, as well as potential problems future surveys may encounter. This research was made possible by the National Science Foundation's Research Experience for Undergraduates program and the National Radio Astronomy Observatory.

332 *Early Science with EVLA* Poster Session *Exhibit Hall*

332.01

EVLA Imaging of Methanimine and Hydrogen Cyanide in Arp 220

Rickert Matthew¹, E. Momjian², A. Sarma¹, AO Arp 220 Team ¹DePaul University, ²National Radio Astronomy Observatory. Exhibit Hall

We used the EVLA in A configuration to image the C-band transitions of the pre-biotic molecule methanimine (H₂CNH) and the J=5 direct I-type transition of hydrogen cyanide (HCN) in the nearest and the prototypical ultra-luminous IR galaxy, Arp 220. The observations were carried out as a result of the first definitive extragalactic detection of these transitions with Arecibo (Salter et al. 2008). These EVLA A-configuration observations spatially resolve the two nuclei of Arp 220, which are separated by about 1 arcsec. The results show that the emission line of the H₂CNH and the absorption line of the HCN (J=5) are solely detected toward the western nucleus of Arp 220. The H₂CNH emission is very likely due to a maser, because its brightness temperature is several times the decomposition temperature of the molecule. This is similar to the formaldehyde (H₂CO) transition, which also shows a weak maser emission line to the western nucleus is in contrast to previous detections of rotationally excited HCN transitions, which have been observed in emission from both nuclei. These EVLA observations, along with Arecibo's original detections, demonstrate that a new range of molecular transitions can now be detected and imaged at cm wavelengths, thus opening up new opportunities for the study of the physical and chemical characteristics of luminous IR galaxies.

The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

333 *Early Results from WISE* Poster Session *Exhibit Hall*

333.02

Observations of Near-Earth Asteroid 2010 CN141 with the Wide-field Infrared Survey Explorer Sean Marshall¹, E. L. Wright²

¹Arizona State University and UCLA, ²UCLA Astronomy.

Exhibit Hall

The near-Earth asteroid 2010 CN141 was discovered by NASA's Wide-Field Infrared Survey Explorer (WISE) in February 2010, with follow-up observations from Mauna Kea by M. Micheli, G. T. Elliott, and D. J. Tholen from February to April. 2010 CN141's low visual albedo and its proximity to Earth caught the attention of observers, and it was selected for more detailed analysis. Its orbit brought it back into WISE's field of view in May, though it was near WISE's detection limit, and it was uncertain whether the asteroid would actually be visible. Subsequent analysis of the relevant WISE frames revealed a faint spot inside the error ellipse that was probably but not conclusively 2010 CN141. The spot was about three arcseconds from the asteroid's expected position. An independent observation from Mauna Kea in April also found a faint object, which was likely 2010 CN141, near the expected coordinates. Thermal modeling of the February observations, using both the Standard Thermal Model (which assumes slow rotation) and the Fast-Rotating Model, indicates that the asteroid has a diameter of 287 m ± 18 m (random) ± 29 m (systematic), a visual geometric albedo of 0.0252 ± 0.0040 (random) ± 0.0051 (systematic), and a bolometric Bond albedo of 0.0099 ± 0.0016 (random) ± 0.0020 (systematic). 2010 CN141 will come relatively close to Earth in the fall of 2011, and there will be good opportunities to observe it for several months.

333.03

The WISE View of Ultracool Brown Dwarfs

Michael Cushing¹, J. Kirkpatrick², A. Mainzer¹, C. Gelino², R. Griffith², M. Skrutskie³ ¹JPL/Caltech, ²IPAC, ³University of Virginia.

Exhibit Hall

One of the primary science goals of the Wide-field Infrared Survey

Explorer (WISE), a NASA MIDEX mission to survey the entire sky at four mid-infrared wavelengths, is to identify the coolest (Teff < 500K) brown dwarfs in the solar neighborhood. Study of these ultracool brown dwarfs will allow us to constrain the low-mass mass function and extend our studies of low-temperature, high-pressure atmospheric physics well into the exoplanet regime. I will present some early results of our brown dwarf program and in particular, will present near-infrared spectra of some of the very late-type T dwarfs we have discovered as well as the initial results of model atmosphere comparisons.

This research was supported [in part] by an appointment to the NASA Postdoctoral Program at the Jet Propulsion Laboratory, administered by Oak Ridge Associated Universities through a contract with NASA.

Intermediate Mass Star Disks in Cygnus X with WISE and Spitzer Photometry

Xavier Koenig¹, D. Leisawitz¹, J. Hora², D. Benford¹

¹NASA Goddard Space Flight Center, ²Smithsonian Astrophysical Observatory.

Exhibit Hall

We present a combined analysis of Spitzer and WISE mid-infrared photometry of more than 500 A and B type stars across the Cygnus X massive star forming complex to study the evolution of disk emission around intermediate mass stars. We find SEDs similar to those of Herbig AeBe stars but also many SEDs that suggest the presence of evolved disks with optically thick outer and optically thin or empty inner disks. Following our finding of similar results in the W4 and W5 regions we argue that these are candidates for disks in the process forming Jovian mass objects. We will use the combined results of these studies to constrain the necessary formation timescales of extrasolar planets as a function of stellar mass.

333.05

Warm Debris Disk Candidates from the Wide-field Infrared Survey Explorer (WISE)

Deborah Padgett¹, W. Liu¹, K. Stapelfeldt², S. Fajardo-Acosta¹, D. Leisawitz³

¹Caltech, ²Jet Propulsion Laboratory, ³GSFC.

Exhibit Hall

The Wide Field Infrared Survey Explorer (WISE) has just completed a sensitive all-sky survey in photometric bands at 3.4, 4.6, 12, and 22 microns. We report on a preliminary investigation of main sequence Hipparcos catalog stars with 22 micron emission in excess of photospheric levels. This warm excess emission traces material in the circumstellar region likely to host terrestrial planets and is preferentially found in young systems with ages < 1 Gyr. Nearly a hundred new warm debris disk candidates are detected among FGK stars within 100 pc and M stars as close as 12 pc, as well as numerous new A star disks. We are in the process of obtaining spectra to determine spectral types and activity level of these stars and have proposed observations to characterize the dust, multiplicity, and substellar companions of these systems. In this contribution, we will discuss source selection methods and individual examples from among the WISE debris disk candidates.

333.06

Stellar Excesses in WISE and Archival IRS Peak-Up

Sergio Fajardo-Acosta¹, S. Blevins², D. Padgett¹, H. Teplitz³, J. Colbert⁴, L. Armus⁴, V. Charmandaris⁵ ¹WSDC/Caltech, ²Cath. U. Am., ³IRSA/Caltech, ⁴SSC/Caltech, ⁵U. Crete, Greece.

Exhibit Hall

In this study we search for excess infrared emission from circumstellar dust debris disks, measured both with the Wide-Field Infrared Survey Explorer (WISE), and the *Spitzer* Infrared Spectrograph (IRS) Peak-Up (PU) arrays. The IRS PU data consist of photometry at 16 and 22 μ m of stellar sources, serendipitously measured for every targeted spectral

observation in the *Spitzer* mission. The data include measurements of ~ 10,000 stars, distributed over an omni-directional sky area of ~ 5 square degrees. We spatially matched these sources with the all-sky WISE survey, to obtain their photometry at 12 and 22 μ m, and with 2MASS, to obtain *J*, *H*, and *K*_s. The 2MASS photometry allows extrapolations of the photospheric SEDs at the WISE and IRS PU bandpasses. We report on the frequency of occurrence of 12, 16, and 22 μ m excess emission from debris disks, for each stellar spectral type, in our unique sample of stars.

Early Results of Flux Variables with WISE Data

Douglas I. Hoffman¹, R. Cutri¹, S. Koshy²

¹IPAC / Caltech, ²California State University Long Beach.

Exhibit Hall

The Wide-field Infrared Survey Explorer (WISE) surveyed the entire sky in four mid-infrared bands, at 3.4, 4.6, 12, and 22 microns during its ~8 month cryogenic mission. The number of independent WISE measurements of a source is a function of its ecliptic latitude. Sources near the ecliptic poles can have hundreds of measurements while sources near the ecliptic plane tend to have as few as eight observations due to the ecliptic polar orbit of the spacecraft. Therefore, the vast majority of detected variable sources and flux transients occur near the ecliptic poles. We present some early results of variable and transient searches in the WISE preliminary data, including light curves of new pulsating and eclipsing stars, as well as peculiar QSO sources. We also detail the selection method used in this project and the the plans for a WISE variable source catalog using the entire mission data.

333.08

First Results From The Wise Infared Excesses Around Degenerates (WIRED) Survey

John H. Debes¹, D. W. Hoard², S. Wachter³, D. T. Leisawitz¹, M. Cohen⁴

¹NASA/GSFC, ²Spitzer Science Center, ³IPAC, ⁴Monterey Institute for Research in Astronomy. Exhibit Hall

The WISE IR Excesses around Degenerates (WIRED) Survey is designed to find low mass companions and dusty disks around white dwarfs using NASA's Wide-field Infared Survey Explorer (WISE) mission. WISE has finished scanning the entire sky, and we have currently cross-correlated the SDSS DR7 white dwarf catalogue with 2MASS, UKIDSS, and WISE photometry to identify candidate excess sources. An overview of the survey is part of a companion presentation at this AAS meeting (Hoard et al.). We show the expected sensitivity level of the WIRED Survey to white dwarfs with dust and/or low mass companions, and present new candidate WISE detections.

This work was supported in part by the NASA Postdoctoral Fellowship Program (J.D.), and is based on data from: WISE, which is a joint project of the University of California, Los Angeles, and the Jet Propulsion Laboratory (JPL), California Institute of Technology(Caltech), funded by NASA; the UKIRT Infrared Deep Sky Survey (UKIDSS); the Two Micron All Sky Survey (2MASS), a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center (IPAC)/Caltech, funded by NASA and the NSF; and the Sloan Digital Sky Survey (SDSS). Funding for the SDSS and SDSS-II was provided by the Alfred P. Sloan Foundation, the Participating Institutions, the NSF, the U. S. Dept. of Energy, NASA, the Japanese Monbukagakusho, the Max Planck Society, and the Higher Education Funding Council for England. We used the SIMBAD database, operated at CDS, Strasbourg, France, and the NASA/IPAC Infrared Science Archive, operated by JPL, Caltech, under a contract with NASA.

333.09

The WISE InfraRed Excesses around Degenerates (WIRED) Survey

D. W. Hoard¹, J. H. Debes², S. Wachter¹, D. T. Leisawitz², M. Cohen³

¹California Institute of Technology, ²NASA's Goddard Space Flight Center, ³Monterey Institute for Research in Astronomy.

Exhibit Hall

The Wide-field Infrared Survey Explorer (WISE) is a NASA medium class Explorer mission that was launched on 14 Dec 2009. WISE mapped the entire sky at 3.4, 4.6, 12, and 22 microns with 5-sigma point source sensitivities of approximately 0.08, 0.11, 1, and 6 mJy, respectively. Complete sky coverage was achieved in mid-July 2010. Prior to the first public release of WISE data planned for Spring 2011, several

early science verification projects are being carried out by the WISE Science Team. The WISE InfraRed Excesses around Degenerates (WIRED) Survey has the goals of characterizing white dwarf (WD) stars in the WISE bands, confirming objects known to have IR excess from past observations (Spitzer, 2MASS, UKIDSS, etc.), and revealing new examples of WDs with IR excess that can be attributed to unresolved companions or debris disks. We are utilizing target lists drawn primarily from the Sloan Digital Sky Survey (SDSS) WD catalogs, as well as a separate sample from the McCook & amp; Sion WD catalog. Preliminary results from the WIRED Survey utilizing 20% sky coverage with the SDSS Data Release 4 WD catalog yielded over 400 detections (S/N > 2) in at least one WISE band, and several new dust disk and WD+brown dwarf binary candidates. We will present an overview of the WIRED Survey results using the full WISE sky coverage with the SDSS Data Release 7 WD catalog (which contains over 18,000 targets). This work was supported in part by the NASA Postdoctoral Program (J.H.D.), and is based on data from: WISE, a joint project of UCLA and JPL/Caltech, funded by NASA; the UKIRT Infrared Deep Sky Survey; the Two Micron All Sky Survey, a joint project of the University of Massachusetts and IPAC/Caltech, funded by NASA and the NSF; and the Sloan Digital Sky Survey.

333.10

A WISE Look at Evolved Massive Stars and Their Environments

Stefanie Wachter¹, M. Cohen², D. Leisawitz³

¹Caltech, ²Monterey Institute for Research in Astronomy (MIRA), ³GSFC. Exhibit Hall

Massive stars play a key role in the chemical and mechanical evolution of the ISM in galaxies. These luminous stars with their strong winds and mass outflows are the dominating influence on their environment in terms of energetics and chemical modification of the ISM. Despite their importance, our knowledge about their formation and evolution is surprisingly limited. In particular, the post main sequence evolution of massive stars, where they shed most of their mass, is poorly understand. Observationally, this stage can be explored through the study of Wolf-Rayet stars (WRs), luminous blue variables (LBVs) and red supergiants (RSGs).

Recently, a large population of obscured evolved massive stars has been revealed by observations with the Spitzer Space Telescope through their prominent circumstellar shells at 24 micron, highlighting that the mid-IR is especially suited to the study of these objects. WISE will for the first time enable an unbiased, comprehensive, and homogeneous look at the known population of evolved massive stars at these wavelengths. We will present WISE photometry and images for evolved massive stars and their environments. As part of this effort, we have already discovered a previously unknown shell around WR 8 at 22 micron. We will provide an overview of the mid-IR morphology of such nebulae for all known WRs and LBVs and a comparison to their optical properties. We will also explore the photometric characteristics of evolved massive stars in the WISE bands. 2MASS and Spitzer data have been used to identify the missing population of highly obscured WRs in the Galaxy. We will define equivalent color criteria for the WISE bands to support similar search efforts with the WISE archive.

333.11

Low Metallicity Blue Compact Galaxies Discovered By WISE

Chao-Wei Tsai¹, R. Griffith¹, J. Wu², D. Stern², L. Yan¹, T. Jarrett¹, P. Eisenhardt², S. Stanford³, D. Benford⁴, F. Harrison⁵, K. Madsen⁵

¹IPAC, Caltech, ²JPL, ³UC Davis, ⁴GSFC, NASA, ⁵Caltech. Exhibit Hall

We present newly discovered low metallicity blue compact galaxies (BCGs) from WISE all sky survey. Between 3.4 and 12 microns, these galaxies share similar WISE colors to red ULIRGs and obscured AGNs. However, they are significantly brighter at optical wavelengths. Our preliminary analysis suggests that about 40% of WISE objects using these criteria are BCGs or their higher luminosity analogs. Keck optical spectroscopy reveals 1/10 Solar or lower metallicities (log[O/H] + 12) in these systems. Future comprehensive follow-up plans of WISE BCG candidates are discussed. These low metallicity, mid-IR bright BCGs will be a unique sample for studying dust grain formation in low metallicity environments, and will help us to understand the thermal dust emission of high-redshift, starburst galaxies.

333.12

A WISE View of Nearby Spiral Galaxies: mapping the spatial distribution of star formation and stellar mass along the Hubble sequence

Frank J. Masci¹, T. Jarrett¹, C. Tsai¹, D. Benford², D. Leisawitz², WISE Team

¹IPAC/Caltech, ²NASA/GSFC.

Exhibit Hall

Spiral density waves are believed to trigger star formation (SF) in spiral arms and determine the gaseous and dynamic evolution of galactic disks. The

Wide-field Infrared Survey Explorer (WISE) offers a unique opportunity to study spiral structure in thousands of galaxies by tracing SF in the mid-IR (12 \&

22 \$\mu\$m) and old stellar populations in the near-IR (3.4 \& 4.6 \$\mu\$m). We present early results of a pilot study of spiral structure in several

grand-design and optically flocculent spirals exhibiting varying degrees of bulge/disk size ratio, spiralarm pitch angle, and absence/presence of bars.

We combine the WISE data with archival UV data to explore the spatial distribution of specific SF rate, stellar mass surface density and

PAH emission across all morphologies. To better match spatial resolutions across wavelengths and accentuate structure on small scales, we use a

resolution enhancement (HiRes) algorithm specifically designed for WISE. We validate our photometric procedures and SF indicators by comparing to

Spitzer measurements of the classic grand-design spiral: NGC 5194 (M51a).

333.13

WISE Discovered Lyman-alpha Emitters and Blobs at z>2

Carrie Bridge¹, A. Blain², S. Petty³, WISE Extragalactic Team

¹Caltech, ²Leicester, United Kingdom, ³UCLA.

Exhibit Hall

The NASA Wide Field Infrared Explorer (WISE) is an all-sky survey mission imaging at 4 bands between 3.4 and 22 microns. A unique power of this mission is its ability to unveil some of the rarest most IR luminous objects in the Universe. Using WISE colors and LRIS on Keck, we serendipitously identified a population of z^2 IR luminous galaxies with Lyman alpha emission (LAE) which in some cases are Lyman alpha Blobs (LABs). Unlike most optically selected LABs however, these WISE selected galaxies are massive ULIRG ($L_{IR} > 10^{12}$) and HyLIRGs ($L_{IR} > 10^{13}$) in energetic phases of formation at a key epoch of galaxy and black hole growth. A third of the sample reside in the LAE pairs, and in one case Lyman alpha emission extends between the galaxies which are separated by ~40kpc. I will present results from the WISE discovered z>2 extended Lyman alpha emitters.

Submillimeter Follow-up Observations for WISE-Selected Galaxies

Jingwen Wu¹, D. Benford², C. Tsai³, A. Blain⁴, C. Bridge⁵, S. Petty⁶, P. Eisenhardt¹ ¹Jet Propulsion Laboratory, ²NASA / GSFC, ³IPAC, ⁴University of Leicester, United Kingdom, ⁵Caltech, ⁶UCLA.

Exhibit Hall

The NASA's Wide-field Infrared Survey Explorer (WISE) has surveyed the entire sky at 3.4, 4.6, 12, 24 microns with hundreds of times better sensitivity than IRAS. One of the scientific goals of the mission is to find the most luminous galaxies in the universe. More than a dozen mid-infrared bright galaxies selected from the WISE survey have been optically identified as high redshift (z >2) galaxies; they are potentially hyperluminous infrared galaxies (HyLIRGs). We have conducted follow-up observations in submillimeter continuum on some of these galaxies and obtain good detections (S/N>3), indicating they have high infrared luminosity and high dust content. We report on our early results.

333.15

WISE Selection Of AGN in the COSMOS Field

Daniel Stern¹, R. Assef¹, D. Benford², R. Griffith³, T. Jarrett³, F. Masci³, S. Petty⁴, C. Tsai³, L. Yan³, WISE Team

¹JPL/ Caltech, ²GSFC, ³IPAC, ⁴UCLA.

Exhibit Hall

The Wide-field Infrared Survey Explorer (WISE) is an extremely capable and efficient black hole finder. We present a simple mid-infrared color criterion, W1-W2 > 0.8 (e.g., [3.4]-[4.6] > 0.8), which identifies 70 AGN candidates per square-degree. This implies a much larger census of luminous AGN than found by typical wide-area optical surveys, attributable to the fact that mid-infrared selection identifies both unobscured (type 1) and obscured (type 2) AGN. Optical and soft X-ray surveys alone are highly biased towards only unobscured AGN, while this simple WISE selection likely identifies even heavily obscured, Compton-thick AGN. Using deep, public data in the COSMOS field, we explore the properties of WISE-selected AGN candidates. At the mid-infrared depths considered, 70 uJy at 3.4 microns and 160 uJy at 4.6 microns, this simple criterion identifies 80% of mid-infrared AGN candidates according to the criteria of Stern et al. (2005) with 80% reliability. We report on the demographics, multiwavelength properties and redshift distribution of WISE-selected AGN candidates in the COSMOS field.

333.16

The Galaxy Angular Two Point Correlation Function from WISE Data

Sean E. Lake¹, E. L. Wright¹

¹UCLA.

Exhibit Hall

The Widefield Infrared Survey Explorer (WISE) satellite has surveyed the entire sky at 3.4 microns to a 5 σ detection depth of 80 µJy or better. Using a preliminary catalogue we have calculated the angular two point function, w(θ), of generic field galaxies using various standard and non-standard techniques. Herein we present a comparison of our results to previous measurements performed using the Sloan Digital Sky Survey (SDSS) and in the COSMOS field.

A WISE/GALEX Study of Massive Early Type Galaxies with UV Excess

Sara M. Petty¹, M. Rich¹, N. Wright¹, C. Bridge², C. Martin²

¹University of California Los Angeles, ²Caltech.

Exhibit Hall

The NASA Wide Field Infrared Explorer (WISE) is an all-sky survey mission imaging at 4 bands between 3.4 and 22 μ m. This new dataset has already discovered some of the most massive, IR luminous objects in the Universe. Nearby early type galaxies are matched using the GALEX/SDSS Medium Imaging Survey sample with the Wide-field Infrared Survey (WISE) catalog. We use our new IR perspective to study massive, early type galaxies. The WISE colors are used to constrain the presence of dust or PAH emission (for those objects with low levels of star formation), or to discern the presence of hidden or low level AGN across the red sequence., Of special interest are the properties of galaxies that fall in the green valley of the UV-optical CMD. We use the GALEX NUV, and the WISE 3.4, 4.6, 12 and 22 μ m photometry to define this color space for massive early types with ongoing star-formation and known AGN.

333.18

MOST - Moving Object Search Tool For NEOWISE And IRSA

Kevin K. Yau¹, S. Groom², H. Teplitz², R. Cutri², A. Mainzer³ ¹*IPAC/Caltech and Raytheon*, ²*IPAC/Caltech*, ³*JPL*.

Exhibit Hall

We present a new web-based tool that will enable researchers to look for serendipitously observed solar system objects contained in the images held by the NASA/IPAC Infrared Science Archive (IRSA) including the single-epoch exposures from WISE. The principal function of MOST is to help researchers to recover NEO, MBA and comet pre-discovery images, that will enable orbit refinement and photometry. MOST takes as input an object name or set of orbital parameters. MOST is able to identify images containing the moving object along the calculated path within the requested time interval. It starts with computing an orbital path spanning the observation times, and fitting a series of search regions covering the path. It then retrieves all the image meta-data within the search regions using an IRSA search function. A post filter utilizing image corner positions and object position computed from image frame time is then employed to identify individual frames containing the object. MOST will be released in April 2011 for use with the WISE archive. MOST will be incorporated with other IRSA archive search and analysis tools to facilitate fast identification and retrieval of images containing moving objects. It will later be expanded to search other IRSA image holdings, including the Spitzer Heritage Archive.

MOST development is sponsored in part by The NEOWISE program, NASA Planetary Division.

333.19

WISE Deep and Wide Survey at 12 Microns

Dominic J. Benford¹, T. Jarrett¹, R. Cutri¹, P. Eisenhardt¹, N. Wright¹, WISE Science Team ¹NASA / GSFC.

Exhibit Hall

We present the first results of a study of faint 12 micron sources detected with the WISE survey mission. A deep field around the north Ecliptic pole provides 5sigma sensitivity of around 100microJy, while a wide field at high Galactic latitude provides an area of around 10 square degrees. Number counts for these sources are compared to smaller area and higher flux surveys carried out by ISO and IRAS. The WISE survey data show a continued increase in sources out to fainter limits.

334 *Surveys and Large Programs* Poster Session *Exhibit Hall*

334.01

Recent Activity at the Astronomical Photographic Data Archive

J. Donald Cline¹, M. Castelaz¹, T. Barker¹

¹*Pisgah Astronomical Research Institute.*

Exhibit Hall

The Astronomical Photographic Data Archive (APDA) located at the Pisgah Astronomical Research Institute (PARI) was established in November 2007. APDA is dedicated to the task of collecting, restoring, preserving and storing astronomical photographic data. APDA is also tasked with scanning each image and establishing a database of images that can be accessed via the Internet by the global community of scientists, researchers and students. APDA is a new type of astronomical observatory one that harnesses analog data of the night sky taken for more than a century and making that data digitally available.

APDA is housed in a newly renovated Research Building on the PARI campus. An award from the NSF allowed renovation of the heating and air conditioning. Plates in APDA are kept in a 20 C +/- 1 C area with humidity at 38% +/- 3%. Renovation of the electrical system with backup power allows for support of a data center with a networked storage system and software donated from EMC Corp. The storage system can hold more than 300 terabytes of research data which can be accessed through multiple gigabyte connectivity to the Internet.

APDA has a collection of more than 100,000 photographic plates and film collections, as well as major instrumentation, from NASA, the STSCI, the US Naval Observatory, the Harvard Smithsonian CfA and others. APDA possesses two high precision glass plate scanners, GAMMA I and GAMMA II, that were built for NASA and the Space Telescope Science Institute (STSCI). The scanners were used to develop the HST Guide Star Catalog and Digitized Sky Survey. We will present the status of GAMMA II and the recent donations of astronomical plates and current research projects.

334.02

SkyDiscovery: Humans and Machines Working Together

Ciro Donalek¹, K. Fang¹, A. J. Drake¹, S. G. Djorgovski¹, M. J. Graham¹, A. Mahabal¹, R. Williams¹ ¹*Caltech.*

Exhibit Hall

Synoptic sky surveys are now discovering tens to hundreds of transient events every clear night, and that data rate is expected to increase dramatically as we move towards the LSST. A key problem is classification of transients, which determines their scientific interest and possible follow-up. Some of the relevant information is contextual, and easily recognizable by humans looking at images, but it is very hard to encode in the data pipelines. Crowdsourcing (aka Citizen Science) provides one possible way to gather such information. SkyDiscovery.org is a website that allows experts and citizen science enthusiasts to work together and share information in a collaborative scientific discovery environment. Currently there are two projects running on the website. In the Event Classification project users help finding candidate transients through a series of questions related to the images shown. Event classification depends very much form the contextual information and humans are remarkably effective at recognizing noise in incomplete heterogeneous data and figuring out which contextual information is important. In the SNHunt project users are requested to look for new objects appearing on images of galaxies taken by the Catalina Real-time Transient Survey, in order to find all the supernovae occurring

in nearby bright galaxies. Images are served alongside with other tools that can help the discovery. A multi level approach allows the complexity of the interface to be tailored to the expertise level of the user. An entry level user can just review images and validate events as being real, while a more advanced user would be able to interact with the data associated to an event. The data gathered will not be only analyzed and used directly for some specific science project, but also to train well-defined algorithms to be used in automating such data analysis in the future.

334.03

Results from DESDM Pipeline on Data From Blanco Cosmology Survey

Shantanu Desai¹, J. Mohr², R. Armstrong¹, E. Bertin³, A. Zenteno², D. Tucker⁴, J. Song⁵, C. Ngeow⁶, H. Lin⁴, G. Bazin², J. Liu², Blanco Cosmology Survey

¹University of Ilinois, Urbana-Champagne, ²LMU, Germany, ³Institute of Astrophysics, France, ⁴Fermilab, ⁵University of Michigan, ⁶National Central University, Taiwan.

Exhibit Hall

The Blanco Cosmology Survey (BCS) is a 60-night survey of the southern skies using the CTIO Blanco 4~m telescope, whose main goal to study cosmic acceleration using galaxy clusters. BCS has carried out observations in two 50 degree patches of the southern skies centered at 23~hr and 5~hr in griz bands. These fields were chosen to maximize overlap with the the South Pole Telescope. The data from this survey has been processed using the Dark energy Data Management System (DESDM) on Teragrid resources at NCSA and CCT.

DESDM is developed to analyze data from the Dark Energy Survey, which begins around 2011 and analysis of real data provides valuable warmup exercise before the DES survey starts. We describe in detail the key steps in producing science ready catalogs from the raw data. This includes detrending, astrometric calibration, photometric calibration, co-addition with psf homogenization. The final catalogs are constructed using model-fitting photometry which includes detailed galaxy fitting models convolved with the local PSF. We illustrate how photometric redshifts of galaxy clusters are estimated using red-sequence fitting and show results from a few clusters.

334.04

Pan-STARRS And Quasars: The Search For Z = 7 Quasars In The Pan-STARRS Dataset Eric P. Morganson¹

¹*MPIA, Germany.*

Exhibit Hall

The Panoramic Survey Telescope and Rapid Response System (Pan-STARRS) is a survey telescope that will image 30,000 square degrees in the optical and near infrared (the grizy filters). Because of its huge area and red filters, Pan-STARRS will be able to identify quasar candidates out to z = 7.5. Because of their intense luminosity, quasars are unique probes of the high redshift universe. Previous high redshift quasar searches have found metal spectral lines, probed the black hole-galaxy mass ratio and measured neutral hydrogen fractions at z > 6. Measuring neutral hydrogen fractions is particularly interesting, because it tells us when reionization occurred and constrains galaxy evolution and star formation models. We have identified 300 high z quasar candidates and will soon be making followup observations at the Calar Alto 3.5 meter telescope and the ESO 2.2 meter telescope.

334.05 A Detailed Study of Photometric Redshifts for Galaxies in the GOODS Fields Tomas Dahlen¹, B. Mobasher²

¹STScI, ²UCR. Exhibit Hall

We use the deepest and the most comprehensive photometric data currently available for GOODS-South and GOODS-North galaxies to measure their photometric redshifts. The photometry spans a wave-length range from the U-band to infrared Spitzer data. The catalogs are selected in the HST/ACS zband (F850LP) and photometry in each band is carried out using the recently completed TFIT algorithm, which performs PSF matched photometry uniformly across different instruments and filters, despite large variations in PSFs and pixel scales. Photometric redshifts are derived using the GOODZ code, which is based on the template fitting method using priors. The code also implements "training" of the template SED set, using available spectroscopic redshifts in order to minimize systematic differences between the templates and the SEDs of the observed galaxies. The scatter between our estimated photometric and spectroscopic redshifts is sigma~0.04. This is consistent with the best results previously published for GOODS-S galaxies, however, the present catalog is the deepest yet available and provides photometric redshifts for significantly more objects to deeper flux limits and higher redshifts than earlier works. Furthermore, we show that the photometric redshifts estimated here for galaxies selected as dropouts are consistent with those expected based on the Lyman break technique. Extensive comparisons between the methods are presented.

334.06

Pulsar Searches with Interferometers

Aaron Berndsen¹, ASKAP ¹University of British Columbia, Canada.

Exhibit Hall

The vast majority of radio pulsars have been discovered with giant single-dish telescopes. Algorithm development is currently underway in preparation for the next generation of radio telescopes, massive interferometers. This poster characterizes some of the anticipated problems and early attempts to ameliorate them.

Funding is through the Canadian SKA Consortium by an NSERC SRO grant, and the ASKAP consortium.

334.07

The C-band All-sky Survey: Progress Of Observations, Data Preview, And Instrument Performance Oliver G. King¹, C-BASS Collaboration

¹California Institute of Technology.

Exhibit Hall

The C-Band All-Sky Survey (C-BASS) is a project that aims to produce sensitive, all-sky maps of Galactic synchrotron emission at 5 GHz in total intensity and linear polarization. These measurements will be used primarily in the subtraction of foregrounds from measurements of the polarized Cosmic Microwave Background. Secondary scientific goals include studying the nature of the Galactic magnetic field, constraining the Galactic cosmic ray energy spectrum, and constraining the so-called "anomalous" microwave emission. Measurements will be performed using a 6 m dish at the Owens Valley Radio Observatory (OVRO) in California, and a 7 m dish in the new Radio Astronomy Park near Carnarvon, South Africa. Northern hemisphere observations have begun and the Southern instrument is at an advanced stage of construction. We discuss the progress of the survey observations, present a preview of the Northern hemisphere data, and discuss the performance of the instrument. The C-BASS project is a collaboration between Caltech/JPL in the US, Oxford and Manchester

Universities in the UK, and Rhodes University and the Hartebeesthoek Radio Astronomy Observatory in South Africa. It is funded by the NSF (AST-0607857) and the participating institutions. http://www.astro.caltech.edu/cbass/

334.08

Progress on the Baker Observatory Sub-minute Survey

Mike Reed¹, J. Gilker¹, M. Thompson¹, L. Hicks¹, A. Quint¹, A. Metzger¹

¹Missouri State Univ..

Exhibit Hall

The Baker Observatory Sub-minute Survey is designed to look for phenomena with short-period variability. Typical exposure times are under 15 seconds, surveying a magnitude range of 10-13 in white light. Known short-period phenomena include pulsating subdwarf B stars, white dwarfs, rapidly oscillating Ap stars and Delta Scuti stars. Currently, most sky surveys are interested in observing the entire sky and as such, the temporal cadence is best suited for variations of several hours or longer. Our survey observes single fields for four hour spans on two separate (non-adjacent) nights. During Phase I of our survey, we have selected 40 fields which contain at least one known variable star. It is then a blind study to determine if we can recover the known variable and search for new variables within each field. Observations for Phase I are nearly complete and we are enhancing our procedures and detection algorithms to optimize sensitivity to variations over many time scales. Our data are excellent for detecting variability shorter than two hours, even down to amplitudes of a millimagnitude (depending on S/N). This material is based upon work supported by the National Science Foundation under Grant No. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation. This work was partially funded by the Missouri Space Grant Consortium, funded by NASA and Missouri State University.

334.09

SAFIRES: Spitzer Archival FIR Extragalactic Survey

Daniel Hanish¹, H. Teplitz², P. Capak², T. Brooke², D. Frayer³, SAFIRES Team ¹Infrared Processing and Analysis Center, ²Spitzer Science Center, ³National Radio Astronomy Observatory.

Exhibit Hall

The Spitzer Science Center's Source List project will enhance the Spitzer Heritage Archive (SHA) by uniformly processing mosaics and extracting individual sources in approximately 1500 square degrees, including approximately 30 million sources. The SSC Source List project will consist of the four Spitzer IRAC channels, between 3 and 8 microns, and the 24-micron MIPS channel. We are in the process of expanding this Source List to take advantage of the sensitivity of the MIPS 70um and 160um imaging modes, resulting in a well-calibrated set of FIR images across approximately 600 square degrees of the extragalactic sky. The resulting list of FIR sources will enable a variety of science projects, such as allowing us to better characterize the FIR luminosity functions and SED evolution of star-forming galaxies.

334.10

Science Validation of the Spitzer Source List

Harry I. Teplitz¹, P. Capak², T. Y. Brooke², D. W. Hoard² ¹Infrared Science Archive (IRSA), ²Spitzer Science Center. Exhibit Hall

The Spitzer Science Center is in the process of generating a source list (SL) that will contain photometry for point sources in a large subset of imaging data in the Spitzer Heritage Archive (SHA). Fully reduced mosaic images and photometry for high significance objects in all four IRAC bands (3.6-4.5 micron) and

the MIPS 24 micron band will be served by the SHA at the NASA Infrared Science Archive (IRSA) as an enhanced data product. These data will include Spitzer observations of about 1500 square degrees and 30 million sources, enabling a large range of exploratory projects and scientific results.

Validation of the source list began by comparing SL measurements to those made by the Legacy science projects. We have now begun an extensive exploration of SL data by undertaking several small, original science projects to independently verify the data products. In the poster we describe the current state of SL processing and discuss the range of use cases which will be supported. We show current results from the on-going validation science projects.

334.11

The Extreme Red: Characterizing LSST's Y3 and Y4 Filters

Michelle Kislak¹, C. Claver², V. Krabbendam², T. Axelrod³

¹University of California Berkeley, ²NOAO, ³University of Arizona.

Exhibit Hall

One of the essential science requirements of the Large Synoptic Survey Telescope lies in its high standard for photometric precision for both photometry and photometric redshift calculation. To capture rest-frame optical spectral features in high-redshift sources, the survey will use a variant of the Y band, which encompasses the reddest hundred nanometers before the Silicon response function cut-off. However, a significant data calibration challenge presents itself with this region of wavelength space: a strongly varying water absorption feature is present directly in the midst of it. In light of this, the survey has proposed two versions of the Y filter, a broad Y4 that includes the water band and a narrower Y3 that excludes it.

In an effort to determine whether the wider filter is characterizable, we undertook an observing campaign with a 4k x 4k ccd camera on the 1.2m Calypso telescope on Kitt Peak to directly compare the properties of the two filters. We present preliminary analysis of this data and the conclusions that can be made from it.

This research was supported by the NOAO/KPNO Research Experiences for Undergraduates (REU) Program which is funded by the National Science Foundation Research Experiences for Undergraduates Program and the Department of Defense ASSURE program through Scientific Program Order No. 13 (AST-0754223) of the Cooperative Agreement No. AST-0132798 between the Association of Universities for Research in Astronomy (AURA) and the NSF.

334.12

Close Binaries Distribution From Mavels First Two Year Survey

Bo Ma¹, J. Ge¹, N. De Lee¹, S. Fleming¹, B. Lee¹, D. C. Nguyen¹, J. Wang¹, J. Pepper², K. Stassun², S. Gaudi³, T. Beers², J. Wisniewski⁴, C. Mack², S. Dhital², M. Paegert², M. Pinsonneault³, J. Xie¹

¹University of Florida, ²Vanderbilt University, ³Ohio state university, ⁴University of Washington. Exhibit Hall

The SDSS-III MARVELS survey is a comprehensive radial velocity survey of 10,000 nearby F-K stars, between 7.6 < V < 12.0. In the first two years approximately 2000 stars have been monitored for signs of radial velocity variability. One of the defining features of this survey is that the observed stars were drawn from a homogeneous sample. Furthermore, the radial velocity observations are independent of the variability of the observed object, thus creating a sample that is unbiased in the time-domain. This makes it uniquely suited to constrain theoretical models regarding the formation of companions and looking at the overall distribution of radial velocity variable objects (Armitage 2007). A survey of this size allows for a detailed analysis of the distribution of close binaries (with Period < 180 day). During the first two years of the six year MARVELS project, approximately 2,000 stars were searched for binaries from 1 to 180 days using a modified Lomb-Scargle periodogram. Here we will

present the preliminary results of an on-going project aimed at deriving the mass ratio and period distribution of close binaries from the first two years of MARVELS survey data.

334.13

Comparison of Derived Stellar Parameters for LAMOST and SEGUE Spectra

Jeffrey L. Carlin¹, H. J. Newberg¹, T. C. Beers², Y. S. Lee², B. Yanny³, L. Deng⁴, H. Zhang⁴, G. Zhao⁴, Y. Zhang⁴, A. Luo⁴, J. Chen⁵, Z. Bai⁵, G. Li⁵, Participants in LAMOST, US (PLUS), LAMOST Project of China ¹Rensselaer Polytechnic Institute, ²Michigan State Univ./JINA, ³Fermi National Accelerator Lab, ⁴National Astronomical Observatories, Chinese Academy of Sciences, China, ⁵LAMOST, China. Exhibit Hall

We have derived estimates of stellar atmospheric parameters (Teff, log g, [Fe/H]) for more than 1000 stars with medium-resolution spectra (*R* = 1800) observed by both SDSS/SEGUE and the LAMOST (Guoshoujing) Telescope. The spectra have been analysed by the current version of the SEGUE Stellar Parameter Pipeline (Lee et al. 2008a, Allende Prieto et al. 2008, Smolinski et al. 2010). The stars cover a wide range of parameter space, similar to that expected to be covered by the LAMOST stellar survey efforts, scheduled to begin within the next year. Despite the fact that the LAMOST 2D pipelines are still in a preliminary stage, and less than ideal wavelength calibrations, flatfielding, and flux calibrations are being used, our comparison of the derived parameters indicates that (at least for many spectra) quite reasonable agreement has been obtained between the two samples. This is an encouraging sign that the LAMOST survey spectra will eventually yield results of similar utility as the SDSS/SEGUE spectra for studies of the stellar populations of the Milky Way, but for at least an order of magnitude more stars spanning much larger, contiguous areas on the sky.

The Participants in LAMOST, US (PLUS) collaboration acknowledges funding from the U.S. National Science Foundation grant AST-0937523. TCB and YSL acknowledge partial funding of this work from grants PHY 02-16783 and PHY 08-22648: Physics Frontier Center/Joint Institute for Nuclear Astrophysics (JINA), awarded by the U.S. National Science Foundation.

334.14

The RESOLVE Survey: REsolved Spectroscopy Of a Local VolumE

Sheila Kannappan¹, M. A. Norris¹, K. D. Eckert¹, A. J. Moffett¹, D. V. Stark¹, M. P. Haynes², R. Giovanelli², A. A. Berlind³, L. H. Wei⁴, A. J. Baker⁵, S. N. Vogel⁴, D. A. Hendel¹, RESOLVE Team ¹Univ. of North Carolina, ²Cornell University, ³Vanderbilt University, ⁴Univ. of Maryland, ⁵Rutgers University.

Exhibit Hall

The RESOLVE Survey is a volume-limited census of stellar, gas, and dynamical mass as well as merging and star formation within 53,000 cubic Mpc of the nearby cosmic web in two long equatorial strips. The survey's primary science drivers include relating the galaxy velocity and mass functions to environment, constraining the "missing baryons" problem from a complete accounting perspective, and understanding galaxy disk building in large-scale context. RESOLVE's unique data product is highresolution multiple-longslit spectroscopy, targeting all ~1500 galaxies with baryonic (stellar + cold gas) mass >~10⁹ Msun in the volume. Combined with a complete redshift survey, this spectroscopy will enable an unprecedented high dynamic-range view of how kinematically estimated mass is distributed on scales from dwarf galaxies to clusters. To trace stellar and gas mass, RESOLVE is drawing on deep public surveys at UV, optical, IR, and radio wavelengths, most notably the 21cm ALFALFA Survey. Here we present early results: (1) statistics of our efforts to recover galaxies missed by RESOLVE's parent survey, the SDSS; (2) calibration of indirect atomic and molecular gas estimators to supplement direct observations; (3) progress toward optimizing stellar mass and environment measures; and (4) a first installment of kinematic data focusing on SO galaxies.

This work is supported by the National Science Foundation under CAREER award 0955368.

334.15

Galaxy Environments and Gas Fraction Trends

David Hendel¹, S. J. Kannappan¹, A. J. Moffett¹, A. A. Berlind², K. D. Eckert¹, N. A. Grogin³ ¹UNC Chapel Hill, ²Vanderbilt University, ³Space Telescope Science Institute. Exhibit Hall

Using both a smoothed density field and group finding, we examine the dependence of atomic gas-tostellar mass ratios on local density and group membership in order to determine whether the previously identified "gas-richness threshold mass" is environmentally dependent. The gas-richness threshold mass, near 5×10^9 M_{sun}, marks the scale below which galaxies with atomic gas-to-stellar mass ratios greater than one emerge abundantly. Whether or not this scale depends on environment will constrain the physical mechanism underlying it. We use two samples, both at low redshift. The first is a volumelimited combined CfA2-SDSS catalog; the other is the NYU VAGC low-redshift catalog. We present the concept and methodology behind the density field calculation, display the results of group finding on the combined CfA2-SDSS sample, examine the correspondence between the two environment metrics, and display the preliminary results of our search for environmental dependence of the threshold mass. We acknowledge the support of the National Space Grant College and Fellowship Program and the North Carolina Space Grant Consortium.

334.16

Bayesian Orbit Determination from Ground-Based Optical Telescopes Michael Schneider $^{\rm 1}$

¹Lawrence Livermore Natl Lab.

Exhibit Hall

We describe a Bayesian sampling model for linking and constraining orbit models from angular observations of "streaks" in optical telescope images. We use Markov Chain Monte Carlo to sample from the joint posterior distribution of the parameters of multiple orbit models (up to the number of observations) and parameters describing the membership probability of each observed streak in each orbit model. Our algorithm allows both for robust preliminary orbit determination and for orbit refinement by sampling from the appropriate conditional distributions. We apply our algorithm to forecast the capabilities of LSST to determine orbits for uncatalogued debris around geosynchronous orbits.

334.17

CRTS: An Open Optical Transient Survey.

Andrew J. Drake¹, S. G. Djorgovski¹, A. Mahabal¹, R. Williams¹, M. J. Graham¹, C. Donalek¹, J. L. Prieto², M. Catelan³, E. Beshore⁴, S. Larson⁴, E. Christensen⁵

¹Caltech, ²Carnegie Observatories, ³PUC Catolica, Chile, ⁴LPL, ⁵Gemini, Chile. Exhibit Hall

The Catalina Real-time Transient Survey (CRTS) is an open optical transient survey that covers 3/4 of the entire sky in a search of transient astrophysical phenomena occurring on timescales of minutes to years. Observational data is derived from the three telescopes of the Catalina Sky Survey which cover up to 2,500 square degrees of sky each night. CRTS has so far discovered more that 2000 transient sources including ~600 supernovae, ~500 dwarf novae and more than 100 Blazars and UV Ceti variables. All data is processed within minutes of observation and discoveries are openly distributed using SkyAlert and VOEvent technologies as well as iPhone, html tables, RSS and Twitter feeds. Events are classified utilizing data from virtual observatory enabled archives, machine learning, and collaborative Citizen science.

335 *Evolution of Galaxies* Poster Session *Exhibit Hall*

335.01 The HST/WFPC2 Lockman Hole Survey

Norman A. Grogin¹, R. S. Somerville¹, R. A. Lucas¹, S. Casertano¹

¹Space Telescope Science Institute.

Exhibit Hall

The Lockman Hole has the lowest HI and Galactic Cirrus foreground of any location in the sky, and is therefore an optimal target for deep X-ray and IR observations. Unlike most other extragalactic deep survey fields in which astronomers have invested extensive amounts of observing time across the electromagnetic spectrum, the Lockman Hole had until recently lacked the comprehensive HST imaging essential to characterize the distant galaxies responsible for emission detected in sensitive imaging at other wavelengths. For example, although total IR flux is central to understanding star formation rates, multiwavelength morphology encodes crucial information necessary to understand galaxy formation history and the physical processes that drive galaxy evolution.

We have remedied this shortfall with one of the last large programs to be executed with HST/WFPC2: a 125-orbit survey of the Lockman Hole in early 2009. This survey comprises 25 WFPC2 pointings, nested into a circular arrangement of radius \approx 7.2 arcmin centered at α = 10h52m43.2s, δ = +57d28m53s. This particular region of the Lockman Hole was chosen because it includes the deepest imaging with XMM and Herschel, ultra-deep Spitzer 24um imaging, and a wealth of ground-based imaging and spectroscopy. Our observations at each pointing are 2 orbits with F606W (wide V-band) and 3 orbits with F814W (I-band), allowing us to reach V \approx 27 and I \approx 26.2 AB mag. These sensitivities enable measurement of rest-frame optical+UV morphologies for several thousand galaxies in the field at z<1. We present initial findings from this survey, including characteristics of our detected HST sources, and results from matching to deep imaging at other wavelengths.

335.03

Color Gradients and Stellar Population Gradients of Early-type Galaxies at z~2 in the Hubble Ultra Deep Field

Yicheng Guo¹, M. Giavalisco¹, P. Cassata¹, A. Koekemoer²

¹University of Massachusetts, Amherst, ²STScl.

Exhibit Hall

We report the detection of color gradients in massive (stellar mass M>10¹⁰ Msun) galaxies with low specific star formation rate (SSFR<10⁻¹¹/yr) at redshift z~2. The galaxies are selected by means of SED fitting to spectral population synthesis models using the Great Observatories Origins Deep Survey (GOODS) broad--band photometry, which spans the optical, near--IR and mid--IR windows, augmented by recent ultra--deep near--IR images obtained with HST WFC3. The estimated stellar mass and SSFR would place these galaxies among today's Hubble early types, while their rest--frame optical morphology, as shown by the WFC3 images, is consistent with that of spheroidal systems. The inner regions of these galaxies are found to have redder rest UV--optical colors than their outer parts. The slope of the color gradient has no obvious dependence on the redshift and stellar mass of the galaxies. It does depend, however, on the overall dust obscuration and rest-frame U-V color of the galaxies mildly, with more obscured or redder galaxies having steeper color gradient. The slope of the color gradient is generally steeper than that of local early-type galaxies. We find that the gradient of a single parameter (age, extinction or metallicity) cannot fully explain the observed color gradient. To study the physical implications of these color gradients, we fit spatially resolved HST seven--bands photometry from ACS and WFC3 images (BVizYJH) in concentric shells across the light profile of each galaxies, sampling the color gradients. Regardless of the assumed metallicity gradient, the redder inner regions always have slightly higher dust obscuration than the bluer outer regions, implying that a dust gradient may partly contribute to the observed color gradients. Because of the age--metallicity degeneracy, the derived age gradient is coupled with the assumed metallicity gradient. We discuss the plausibility and implication of each derived age gradient.

335.04

Looking For The "Green Valley" In Compact Group CMDs

Natalie Butterfield¹, L. Walker¹, K. Johnson¹

¹University of Virginia.

Exhibit Hall

Compact Groups of galaxies have low velocity dispersions and high number densities, similar to the environment of the earlier universe. Recent work on a core sample of twelve compact groups has led to the discovery of a gap in mid-infrared IRAC (3.5-8 micron) colorspace (Johnson et al. 2007) as well as specific star formation rates (Tzanavaris et al. 2010). To follow up this research we investigate the optical color-magnitude diagram (CMD) for a comprehensive sample of compact groups. We compare the distribution in the optical CMD with the IRAC colorspace distribution to see whether the IRAC gap corresponds to the optical green valley. A galaxy's location in IRAC colorspace indicates the galaxy's level of activity, thus combining optical and mid-infrared data gives us an unobscured view of what is transpiring in the galaxy. In order to gain insight into the evolution of galaxies both inside and outside of the compact group environment, we also compare the optical CMD of compact group galaxies to those from the Sloan survey. This comparison indicates that compact group galaxies occupy the optical CMD differently than field galaxies in general.

335.05

Duty Cycle and the Exponentially Increasing History of Star Formation of z>=6 Galaxies Jason Jaacks¹, K. Nagamine¹, J. Choi²

¹University of Nevada Las Vegas, ²University of Kentucky. Exhibit Hall

Using cosmological hydrodynamic simulations, we find good consistency between the simulations and observed photometric properties of z=9 to z=6 galaxies, such as the color-color diagrams and rest-frame UV luminosity function. By performing a fit to the Schechter luminosity function we find an evolving faint-end luminosity slope of -2.00 and steeper for z=6 to z=9, suggesting a significant population of small faint galaxies which are currently beyond our observational limits. Motivated by our concurrence with the observed photometric properties, we explore the duty cycle, star formation histories (SFH) and number densities of these high-z galaxies. We find that although individual galaxies have bursty SFH, the mean SFH show a clear exponentially increasing SFH with time-scales ranging from 70 Myr to 200 Myr for galaxies with Mstar=10⁶ to 10¹⁰ Msun. We also calculate the duty cycle of star formation above an observable star formation threshold, and find that it makes a steep transition from zero to unity between Mstar=10⁷ to 10⁹ Msun.

335.06 **The Mass-radius Relation For Starforming Galaxies At z ~ 2-3 Sarah Nagy**¹, D. R. Law¹, C. C. Steidel², A. E. Shapley¹

Sarah Nagy⁻, D. R. Law⁻, C. C. Steidel⁻, A. E ¹UCLA, ²Caltech.

Exhibit Hall

We present early results from an ongoing HST/WFC3 rest-frame optical imaging survey of star-forming galaxies in the redshift range 1.5 < z < 3.5. With 42 orbits of F160W imaging distributed amongst 10 survey fields, our survey will ultimately cover 65 square arcmin to a depth of 27.9 AB and contain > 300 spectroscopically confirmed galaxies with stellar masses in the range $M^* = 1e9 - 1e11$ solar masses. We discuss the form of the relation between stellar mass and rest-frame optical effective radius, how this relation evolves from $z \sim 3$ to $z \sim 1.5$, and how it compares to the local starforming galaxy population.

335.07

Examining the Role of Environment in a Comprehensive Sample of Compact Groups

Lisa May Walker¹, K. E. Johnson¹, S. C. Gallagher², J. E. Hibbard³, A. E. Hornschemeier⁴, P. Tzanavaris⁴, J. C. Charlton⁵

¹University of Virginia, ²University of Western Ontario, Canada, ³NRAO, ⁴NASA, ⁵Penn State. Exhibit Hall

Compact groups, with their high number densities, small velocity dispersions, and the presence of neutral gas, provide a local analog to the early universe. The frequent and prolonged gravitational encounters which occur in compact groups affect the evolution of the constituent galaxies in miriad ways. Recent discovery of a gap in mid-infrared (MIR) IRAC (3.5-8 micron) colorspace and an analogous gap in their specific star formation rates are an interesting new example of how compact groups affect their member galaxies. In order to investigate the origin and nature of this gap, we have determined the IRAC colors of an expanded sample of 35 compact groups in addition to the original 12 studied by Johnson et al. (2007). We find that the gap in IRAC colorspace is still present in the larger sample. There are more galaxies which fall in the gap region, but there is still a dearth relative to the number of galaxies throughout IRAC colorspace, most notably it will allow us to investigate properties of galaxies which fall in the gap.

335.08

Molecular Gas, AGN Feedback and the Unusual Case of NGC 1266

Katherine A. Alatalo¹, T. A. Davis², L. Blitz¹, L. M. Young³, M. Bureau², L. A. Lopez⁴, M. Cappellari², E. Emsellem⁵, D. Krajnović⁵, R. M. McDermid⁶, ATLAS 3-D Team

¹UC, Berkeley, ²Oxford University, United Kingdom, ³New Mexico Tech, ⁴UC, Santa Cruz, ⁵ESO, Germany, ⁶Gemini Observatory.

Exhibit Hall

NGC 1266 is an SO galaxy that was observed in multiple wavelengths as part of the Atlas3d effort which remarkably hosts about 10⁹ solar masses of molecular gas and has a spectrum that exhibits extended wings of up to +/-400 km/s. High resolution CARMA observations have shed further light on this galaxy and revealed that the bulk of the gas is concentrated within 100pc of the nucleus. Combined with the presence of an AGN and molecular gas outflowing faster than vesc, this galaxy is an excellent candidate for AGN feedback. If so, it is the first example of molecular feedback into the IGM from a relatively normal galaxy. How the gas fell so deeply into the potential well, and the exact nature of the driving mechanism behind the expulsion of the gas remain mysteries. Funding for the operation of CARMA comes from the National Science Foundation and the consortium universities.

COS Observations of Molecular H_2 at z = 0.248

Ethan Kruse¹, J. Tumlinson², C. Thom², K. Sembach²

¹Harvard University, ²STScI.

Exhibit Hall

We present HST/COS observations of a QSO sightline through the halo of two merging galaxies at z =0.25 at impact parameter 90 kpc. This sightline presents the first example of strong H_2 absorption features in our large COS survey of galaxy halo gas at low redshift (COS-Halos, Tumlinson et al.). COS spectra reveal a sub-DLA at z = 0.2478 which splits into two components separated by 70 km/s. One component appears to contain more high-ionization states and less neutral H I while the other favors neutral atoms and contains a strong H₂ signature (J = 0-3) along with the majority of the H I. Aside from H_2 we detect O I, N I and N II, Si II and Si III, and C II. We find a total H_2 column density of N(H_2) = 16.89 and an H₂ fraction of f $\{H_2\}$ = 0.0034. Fitting the unblended H₂ lines from 0-0 to 15-0 to a curve of growth we find a best fit with $b = 11.8 \text{ km s}^{-1}$. Due to the full saturation of all Lyman lines, we are unable to separate the H I column density into the two components and therefore cannot get a direct metallicity for either cloud. However through Cloudy modelling we are able to estimate a H I column density and ionization correction in each component and therefore obtain an approximate metallicity through O I absorption. This system shows similar features to a portion of the Magellanic Stream studied by Sembach et al. 2006. Both sightlines have comparable H I and H₂ columns, H₂ excitation temperatures, and similar metallicities, suggesting this sightline could be a distant counterpart to the Magellanic Stream, perhaps stripped from an unseen companion galaxy to the two merger partners.

335.10

The Formaldehyde Deep Field: A Mass-Limited, Distance-Independent, Extinction-Free Census of Cosmic Star Formation

Jeremiah K. Darling¹, B. Zeiger¹

¹University of Colorado.

Exhibit Hall

We examine the absorption of cosmic microwave background (CMB) photons by formaldehyde (H₂CO) over cosmic time. Centimeter-wave rotational transitions of H₂CO become ``refrigerated'' by collisions with molecular hydrogen, driving their excitation temperatures below the CMB temperature. We demonstrate that the H₂CO excitation and detectability is nearly independent of redshift or gas kinetic temperature. H₂CO is thus a nearly distance-independent, extinction-free, molecular gas mass-limited tracer of galaxies and the cosmic star formation history. Moreover, H₂CO line ratios provide a measurement of molecular gas density. A Formaldehyde Deep Field will be possible with large bandwidth sensitive radio interferometers such as the EVLA, spanning nearly the full history of star formation with uniform sensitivity in a single observation. This research was supported by NSF grant AST-0707713.

335.11

Stellar Populations of Fossil Group Galaxies

Naomi Pequette¹, K. Alexander², E. M. Wilcots³

¹University of Denver, ²Brown University, ³University of Wisconsin-Madison. Exhibit Hall

Fossil groups are thought to be the remnants of groups of galaxies in which all the component galaxies have merged. Left behind is one, large, elliptical galaxy (sometimes surrounded by faint remnants of the group), which has a mass and X-ray luminosity comparable to an entire group of galaxies. It is thought that these objects are the end state of evolution for a galaxy group and have not undergone a major

merger in the past 1 Gyr. This makes them ideal for studying characteristics intrinsic to the group environment. We studied a sample of seven candidate fossil groups, selected from Santos et al. 2007, using the SparsePak Integral Field Unit and Bench Spectrograph on the WIYN 3.5m telescope (Kitt Peak, AZ). Here, we present the results of our spectroscopic survey. We correlated our data with multiwavelength observations of these galaxies, including the Hess et al. (2010) radio continuum observations, and found evidence of AGN activity. To better understand if the AGN is correlated with the star formation history of the fossil group, we used our spectroscopic data and data from SDSS to investigate the stellar populations of the central elliptical galaxies. Fitting these data with a stellar population synthesis model, we find that the star formation history of these galaxies is broadly consistent with the theory that these galaxy groups formed through minor mergers. This research was supported by the NSF/REU grant AST-1004881 and the University of Wisconsin-Madison.

335.12

The Star Formation History of Mass-selected Galaxies in the Cosmos Field Alexander Karim¹

¹Max-Planck Institute for Astronomy, Germany.

Exhibit Hall

In recent years, multi-wavelength look-back surveys revealed how galaxies build up their stellar mass and how their star formation rates (SFRs) evolve probing a wide range of redshift. The panchromatic datasets of the COSMOS field, in particular, has provided very accurate photometric redshifts and stellar masses for an unprecedentedly rich mass-selected sample of galaxies. Stacking these data into the VLA-COSMOS 1.4 GHz map we have determined the average SFR of galaxies as a function of stellar mass unbiased from dust/extinction effects and source confusion due to the 1.5" angular resolution achieved by the VLA. We confirm the existence of a power-law relation between specific SFR (SSFR) and stellar mass for star forming galaxies out to z=3. While higher mass systems exhibit lower SSFRs at any epoch NO differential, more rapid evolution of high mass galaxies is evident. We describe the massindependent temporal evolution of the SSFR by a simple power-law (1+z)ⁿ. Utilizing measured mass functions of star forming systems, the characteristic stellar mass for galaxies contributing most to the comoving SFR density does not appear to evolve with cosmic time. Our data presents the to-date best determination of the cosmic star formation history since z~3.

A central implicit assumption of this work is the validity of the radio-IR relation at all relevant redshifts. By considering Spitzer/MIPS 24 and 70µm data for the same sample of galaxies we were able to show that radio- and IR-based derived SFRs are in good agreement.

335.13

The Stellar Population Completeness of Narrow-band Emission-line Surveys

Chun Ly¹, M. A. Malkan², N. Ross², K. Ota³, N. Kashikawa⁴, M. Iye⁴

¹Space Telescope Science Institute, ²UC, Los Angeles, ³Cosmic Radiation Laboratory, Japan, ⁴National Astronomical Observatory, Japan, Japan.

Exhibit Hall

Narrow-band surveys have been conducted to identify high redshift star-forming galaxies by detecting their nebular emission lines when redshifted into narrow bandpasses. Such surveys have yielded large samples from low redshifts (z<0.4) to as high as z=7. These surveys have the ability to (1) measure redshifts to 1 percent accuracy, (2) derive robust emission line fluxes, which can be used to determine star-formation rates (SFRs) and trace the cosmic SFR density, and (3) is roughly ten times more efficient than spectroscopic surveys in terms of (1) and (2).

In this poster, we illustrate a unique advantage of these narrow-band surveys in identifying star-forming

galaxies that span a wide range of physical properties. This survey is the first to study the stellar population completeness of emission-line surveys. It utilizes two samples of [O II] emitters at z=1.47 and z=1.61 in the Subaru Deep Field. The survey consists of ~1,200 emission-line galaxies with accurate photometric redshifts, and photometric coverage over 22 wave-bands (1500 Angstroms to 4.5 μ m). We find that these [O II] samples simultaneously probed the two extremes (from the bluest to the reddest) of galaxy populations. That is, the [O II] emitters are also selected as BX/BM (UV) galaxies and/or the star-forming BzK (NIR) galaxies. We attribute this success to the adopted low minimum observed equivalent width (EW) of 10 Angstroms. In addition, we find that roughly 10% of the z=1.47 [O II] emitters are not selected by either the UV or NIR techniques. These galaxies have the reddest rest-frame optical colors and very low [O II] EWs. We argue that ultra-deep narrow-band surveys are able to catch the most reddenned galaxies by detecting their weak, dust-obscured emission lines, which standard color selections, including NIR techniques, miss.

335.14

Which Stellar Population Synthesis Model Fits The Observed Properties Of Post-starburst Galaxies Best?

Bronson Wacker¹, G. Rudnick¹, C. Tremonti²

¹University of Kansas, ²University of Wisconsin-Madison.

Exhibit Hall

Stellar Population Synthesis models are a critical component of our current understanding of galaxy formation and evolution. Unfortunately they suffer from systematic errors from their implementation of various stages of stellar evolution. For example, young stellar populations (~ 1 Gyr) include TP-AGB stars, which are high contributors to the population (primarily in the near-IR) and troublesome to model. In an effort to optimize choice of the various models available, based on physically motivated criteria, we utilize Post-Starburst galaxies taken jointly from the SDSS DR7 and UKIDSS DR5 (0.05 & lt; z & lt; 0.25) to compare their optical and near-IR properties to those predicted by various SPS models, e.g. BCO3 and M05. We have developed a Bayesian technique to determine which SPS model correctly predicts the SED of Post-Starburst galaxies, i.e. answering the question: "which model fits the data best?"

335.15

Stellar Content of the Most Massive Galaxies

Michael D. Hoenig¹, A. Fritz², R. P. Schiavon¹

¹Gemini Observatory, ²INAF, Italy.

Exhibit Hall

Understanding the formation and properties of massive galaxies allows us to constrain models of galaxy formation. In the Λ CDM framework, massive galaxies are assumed to form by a combination of dry mergers at *z* < 1 and AGN feedback. A third of the present day brightest cluster galaxies are expected to have built up half their mass since *z* = 0.5.

We introduce our new project which aims to examine a well-defined sample of massive galaxies at 0.1 < z < 0.4, selected from the SDSS database. Optical HST/ACS imaging as well as Gemini/GMOS spectroscopy has been obtained for our objects. Due to the high signal-to-noise of the galaxy spectra, we are able to perform a detailed study of the kinematics and stellar populations of the galaxies. We will present the fundamental plane as well as accurate new measurements of the internal dynamics for our sample.

Cool Gaseous Outflows and the Spatial Distribution of Star Formation in Galaxies at 0.3 < z < 1.4 Kate H. Rubin¹

¹Max-Planck-Institut für Astronomie, Germany. Exhibit Hall

Current models of galaxy evolution require that galactic-scale gaseous outflows play an integral role in shaping the observed galaxy stellar mass function. The implementation of winds in these models, however, has been primarily via ad hoc prescriptions, as the physics driving such outflows is not understood. In particular, theoretical studies suggest that high spatial concentrations of star formation activity may be physically responsible for the development of an outflow; however, the relationship between host galaxy SFR surface density and outflow kinematics in distant galaxies remains poorly constrained. To address these questions, we present an analysis of absorption and emission line profiles for the MgII 2796, 2803 and FeII 2586, 2600 transitions in individual spectra of ~120 galaxies at 0.3 < z < 1.4 selected from the GOODS fields and the Extended Groth Strip. We identify outflows of cool $(T^{10^4} K)$ gas via the blueshift of the absorption lines, and measure outflow velocities and column densities taking into consideration the effects of photon scattering on the observed profiles. Using high resolution HST/ACS imaging to estimate the size of the star forming regions in the host galaxies in tandem with measurements of total SFRs, we present one of the first explorations of trends in outflow properties with host galaxy SFR surface density. Initial results suggest only a weak dependence of outflow velocity on SFR and SFR surface density, with outflows occuring in galaxies over the full range in SFR surface density probed.

335.17

Mass-metallicity Relation Of Star-forming Galaxies From HST/ACS PEARS At 0.2 < z < 0.8 Lifang Xia¹, S. Malhotra¹, J. Rhoads¹

¹Arizona State University.

Exhibit Hall

We present the M-Z (mass-metallicity) relation for 30 star-forming galaxies at 0.2 < z < 0.8 in HST/ACS PEARS by the Magellan LDSS-3 spectroscopy. The M-Z relation of the PEARS galaxies shows large offset by ~ -0.5 dex in metallicity at given stellar mass relative to the local M-Z relation from SDSS galaxies. The L-Z relation is offset by ~ -0.8 dex in metallicity for a given rest-frame B absolute magnitude relative to the local L-Z relation. The low metallicity galaxies in the PEARS sample show very blue colors, small sizes, and compact disturbed morphologies, and are similar to the studied local LBG analogs and "green peas" with SSFR > 10^{-9} yr⁻¹. After excluding the highly disturbed and elongated galaxies, the gas-phase oxygen abundance shows a positive relation with the galaxy sizes, which is linearly fitted as $12 + \log(O/H) = 0.09$ (dex/kpc) $r_{hir} + 8.13$. From the physical properties of the low metallicity PEARS galaxies, blue colors, compact disturbed morphologies, high SSFRs, the tidal interacting induced inflow of metal-poor gas may account for the low metallicities of these galaxies and the large offset of the PEARS galaxies in the L-Z and the M-Z relations relative to the local relations.

Support for program was provided by NASA through a grant from the STSI, which is operated by the AURA under NASA contract NASA5-26555 and is supported by HST grant 10530.

Results From Medium Deep Near-UV Imaging With The HST/WFC3 Early Release Science Data

Seth H. Cohen¹, R. E. Ryan Jr.², N. P. Hathi³, A. N. Straughn⁴, H. Yan⁵, M. J. Rutkowski¹, R. A. Windhorst¹, P. J. McCarthy³, R. W. O'Connell⁶, A. M. Koekemoer⁷, WFC3 SOC

¹Arizona State Univ., ²UC Davis, ³OCIW, ⁴GSFC, ⁵Ohio State, ⁶UVa, ⁷STScI. Exhibit Hall

As part of the WFC3 Early Release Science observations, a portion of the GOODS-S field was observed with both the UVIS and IR Channels of the WFC3. The full data set of 100 orbits covers 50 square arcminutes on the sky at 0.09 arcseconds per pixel with ten broad bands covering 0.2-1.7 microns. The field was observed in F225W, F275W, and F336W to 10 sigma point source flux limits of 26.0, 26.1, and 25.7 AB-mag, respectively. In this poster, we will emphasize the results enabled by these UV observations of faint galaxies. We demonstrate that these UV observations are extremely useful, even for galaxies of intermediate redshifts (z<1), in terms of SED fittings, photometric redshifts, dropout galaxies, AGN, etc. In particular, optical and near-IR studies only measure the rest-frame UV properties of the highest redshift galaxies, and for comparison these UV observations are needed to properly study galaxy evolution near the peak of the global star formation rate density. In fact, deeper UV observations, below the atmospheric cutoff, and with space-based resolution, are need to properly study galaxies at the

faint-end of the luminosity function at z^{-1} .

This paper is based on Early Release Science observations made by the WFC3 Scientific Oversight Committee. We are grateful to the Director of the Space Telescope Science Institute for awarding Director's Discretionary time for this program. Support for program #11359 was provided by NASA through a grant from the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS 5-26555.

335.19

HST WFC3 Early Release Science: Emission-line Galaxies from IR Grism Observations

Amber Straughn¹, H. Kuntschner², M. Kuemmel², J. Walsh², S. Cohen³, J. P. Gardner¹, R. A. Windhorst³, R. W. O'Connell⁴, N. Pirzkal⁵, G. Meurer⁶, P. J. McCarthy⁷, N. P. Hathi⁷, S. Malhotra³, J. Rhoads³, WFC3 SOC ¹NASA'S Goddard Space Flight Center, ²ST-ECF, Germany, ³Arizona State University, ⁴University of Virginia, ⁵Space Telescope Science Institute, ⁶University of Western Australia, Australia, ⁷Observatories of the Carnegie Institute of Washington.

Exhibit Hall

The Early Release Science II program for HST WFC3 includes one pointing observed with the G102 (0.8-1.1 microns; R~210) and G141 (1.1-1.6 microns; R~130) infrared grisms at a depth of 2 orbits/grism. From this data we detect 48 actively star-forming emission-line galaxies and measure the galaxies' redshifts, line fluxes, star-formation rates, and masses. In particular, the prominent emission lines H α , [OII], and [OIII] fall into the two infrared grism bandpasses over a redshift range z=0.2-3.6, and the majority of galaxies have at least two lines in the observable wavelength range resulting in secure line identification and redshift determination. We detect galaxies with line fluxes to ~3 x 10⁻¹⁷ erg/s/cm² as well as several sources with very high EW lines. The higher spectral resolution and sensitivity of the WFC3 grisms over previous instrumentation also allows detection of other emission lines in some galaxies. The average magnitude of the emission-line galaxy sample is m_{AB}(F098M)=23.6 mag with more than 20% of the sample fainter than m_{AB}(F098M)=25 mag, demonstrating the remarkable efficiency and capability of the WFC3 NIR grisms for measuring galaxy properties to faint magnitudes and intermediate redshifts. Our results point to the promising potential for future science with WFC3 grism spectroscopy, as well as upcoming missions such as JWST and WFIRST. This paper is based on Early Release Science observations made by the WFC3 Scientific Oversight Committee. We are grateful to the Director of the Space Telescope Science Institute for awarding Director's Discretionary time for this program. This research was supported in part by an appointment to the NASA Postdoctoral Program at Goddard Space Flight Center, administered by Oak Ridge Associated Universities through a contract with NASA (ANS).

335.20

Multiwavelength Morphologies of Star-Forming Galaxies at Intermediate Redshifts

Sandra M. Blevins¹, E. N. Voyer¹, D. F. de Mello¹, H. I. Teplitz², B. Siana² ¹Catholic University of America, ²California Institute of Technology. Exhibit Hall

We present preliminary work providing insight into the formation epoch of the Hubble types. We use HST (ACS and WFC3) multiple wavelengths (FUV, U, B, V, i, z, J, H, K, where available) images to analyze the morphology of a sample of 317 star-forming galaxies. This sample is FUV-selected containing star-forming galaxies at intermediate-redshifts (0.1 < z < 1) in the Great Observatories Origins Deep Survey (GOODS) fields. We investigate quantitative morphologies of galaxies versus their spectral types for the FUV sample using rest-frame optical GALFIT morphological parameters and spectral types obtained from GOODS catalogs.

335.21

Observations Of CO 1-0 Line Emission In "normal" Star-forming Galaxies At z=1.5

Manuel Aravena¹, C. Carilli¹, E. Daddi², J. Wagg³, F. Walter⁴, D. Riechers⁵, H. Dannerbauer², G. Morrison⁶, D. Stern⁷, M. Krips⁸

¹National Radio Astronomy Observatory, ²CEA Saclay, France, ³European Southern Observatory, Chile, ⁴Max-Planck Institute for Astronomy, Germany, ⁵California Institute for Technology, ⁶Institute for Astronomy, University of Hawaii, ⁷Jet Propulsion Laboratory, California Institute for Technology, ⁸Institute de Radio Astronomie Millimetrique, France.

Exhibit Hall

Observations of the CO 1-0 line emission in galaxies directly trace the molecular gas mass, being crucial to estimate the excitation conditions of the molecular gas. Here, we present the first detections of the CO 1-0 line in three BzK-selected galaxies at z=1.5 with the VLA and GBT. This observations allowed us to confirm the low excitation of the gas compared to that of QSOs at similar redshifts. New observations with the EVLA are crucial to measure the extent and kinematics of the cold gas component of the ISM in these "normal" star-forming galaxies at high-redshift.

335.22

Massive Galaxies at z=2-3: A Large Population of Disky Star-Forming Systems?

Tim Weinzirl¹, S. Jogee¹, GOODS-NICMOS Collaboration

¹University of Texas at Austin.

Exhibit Hall

The assembly modes via which galaxies develop their present-day mass and structure remain hotly debated. We explore this issue using one of the largest samples of massive galaxies (166 with stellar mass $M_{star} \ge 5 \times 10^{10} M_{\odot}$) at z=1-3 with NICMOS F160W observations from the GOODS NICMOS Survey (GNS), along with complementary ACS, *Spitzer*, and Chandra data. Our findings are:

(1) The majority of the massive galaxies at z=2-3 have a disky structure (as characterized by the index of single-component Sersic profiles). Most are also compact with half-light radii less than 2 kpc. These massive galaxies at z=2-3 appear to be radically different in structure from their more massive descendants at z^{-0} . Through artificial redshifting experiments based on redshifted simulated NICMOS data of such massive z^{-0} elliptical, S0, and spiral galaxies, we show that most of this difference in structure is not due to cosmological or instrumental effects. This implies that significant structural

evolution is needed to convert the massive z=2-3 systems into their $z\sim0$ elliptical and S0 descendants, and places important constraints on the associated evolutionary mechanisms (e.g., major mergers and cold accretion).

(2) Using IR luminosities inferred from *Spitzer* detections, we find that over z=1-3, the mean star formation rate (SFR) rises substantially, even if AGN candidates are excluded. SFRs of several hundred solar masses per year or higher are common. The results imply a much higher average cold gas fraction than exists in $z^{\sim} 0$ galaxies.

(3) We identify AGN candidates using a variety of techniques (X-ray properties, IR power-law, and IR-tooptical excess) and classify about one-third of the massive galaxies at z=1-3 as AGN hosts. The AGN fraction rises with redshift and is ~ 40% at z=2-3. A significant fraction of the AGN candidates have disky structures although they host massive black holes.

335.23

Host Galaxies and Black Hole Growth at z~1

C. Megan Urry¹, C. N. Cardamone², K. Schawinski¹, E. Treister³, G. Brammer⁴, E. J. Gawiser⁵ ¹Yale Univ., ²MIT, ³Institute for Astronomy, ⁴European Southern Observatory, Chile, ⁵Rutgers Univ.. Exhibit Hall

We investigate the co-evolution of galaxies and black holes at the epoch of maximum growth, comparing normal galaxies and active galactic nucleus (AGN) host galaxies at $z \sim 1$, using new, highly accurate photometric redshifts from the MUSYC medium-band survey in the Extended Chandra Deep Field-South (ECDF-S) and correcting for reddening using rest-frame near-infrared colors and SED fitting. The distribution of AGN host galaxies in color space is identical to that of normal (inactive) galaxies, at least for log M > 10 MSun, where the sample is complete. After dust correction, few AGN hosts lie in the green valley, unlike the situation at $z \sim 0$. Instead, at $z \sim 1$, AGN activity is roughly evenly split between two modes of black hole growth: the first in passively evolving host galaxies, which may be heating up the galaxy's gas and preventing future episodes of star formation, and the second in dust-reddened young galaxies, which may be ionizing the galaxy's interstellar medium and shutting down star formation.

335.24

Fueling Supermassive Black Holes in High-Resolution Cosmological Simulations

Robyn D. Levine¹, N. Y. Gnedin², A. J. S. Hamilton³

¹CITA, Canada, ²Fermilab, ³JILA, U. Colorado.

Exhibit Hall

The growth of supermassive black holes (SMBHs) in the centers of galaxies is a rich and complex problem, spanning a large dynamic range and depending on many physical processes. Simulating the transport of gas and angular momentum from super-galactic scales all the way down to the accretion disk requires sophisticated numerical techniques with extensive treatment of baryonic physics. We use a hydrodynamic adaptive mesh refinement simulation to follow the growth and evolution of a typical disk galaxy hosting a SMBH, in a cosmological context. We have adopted a piecemeal approach, focusing our attention on the gas dynamics in the central few hundred parsecs of the simulated galaxy (with boundary conditions provided by the larger cosmological simulation), and beginning with a simplified picture (no mergers or feedback). In this scenario, we find that the circumnuclear disk remains marginally stable against catastrophic fragmentation, allowing stochastic fueling of gas into the vicinity of the SMBH.

Central Black Hole Growth in Galaxies: Normal, Active, and Merging

Timothy S. Hamilton¹, N. N. Jetha², J. Thompson³

¹Shawnee State University, ²University of Alabama, Huntsville, ³Marshall University. Exhibit Hall

The mass ratio of central black holes to galaxy bulges is not constant but grows over the lifetime of the galaxies. While other groups have looked at changes over cosmic time or with galaxy mass, we show a dependence on the time since the last major galactic merger.

* E and SO galaxies in groups and clusters (but not field galaxies) show an early, steep rise in mass ratio that becomes slower in old galaxies. Additional work is underway to separate truly isolated galaxies from fossil groups (those that have merged with all companions), which would be expected to show the growth pattern.

* Both radio and optical AGN show different patterns from normal galaxies. All AGN have high black hole/bulge mass ratios, regardless of age, but radio AGN have the highest mass ratios and are skewed towards older galaxies.

* Time is measured by the age of a galaxy's dominant stellar population, which is expected to measure time since the last major galactic merger. Thus activity showing up in "old" galaxies would have to be triggered by minor mergers (without producing a burst of star formation) or other events, such as disk and bar instabilities. These results allow us to test galaxy evolution models.

335.26

Outbursts from Supermassive Black Holes

Christine Jones¹, W. Forman¹, R. Kraft¹

¹Harvard-Smithsonian, CfA.

Exhibit Hall

At high redshifts, supermassive black holes can be radiatively bright, producing AGN (e.g. QSOs and BL Lacs) that are more luminous than entire galaxies. In the local Universe, the supermassive black holes that reside in the centers of most galaxies are generally radiatively quiet. However, many of these supermassive black holes do exhibit occasional outbursts that are seen through radio jets and in cavities or shocks in the surrounding X-ray atmospheres. In these low redshift systems, the kinetic energy of the outburst, that needed to produce the shocks and bubbles, exceeds the radiative output of the supermassive black hole by orders of magnitude. While most high redshift AGN are not in gas rich environments, where the kinetic energy of the supermassive black holes could be measured directly, we have collected a small sample of AGN with surrounding hot gas, and an even smaller sample that show X-ray cavities in the gas. In this contribution, we will compare the radiative and kinetic energies of high redshift AGN with their low redshift counterparts.

335.27

Shocked Molecular Hydrogen Emission in the Taffy Galaxy Bridge

Philip N. Appleton¹, B. W. Peterson², G. Helou³, T. H. Jarrett⁴, M. Cluver⁵, P. Ogle⁵, P. Guillard⁵, F. Boulanger⁶

¹NHSC, Caltech, ²Iowa State, ³Caltech, ⁴WISE Data Center, Caltech, ⁵SSC, Caltech, ⁶IAS, France. Exhibit Hall

Observations of the Taffy Galaxies with the Infrared Spectrograph (IRS) on the Spitzer Space Telescope have revealed powerful rotational lines of molecular hydrogen from both the galaxy disks and the bridge region between them. The emission shows strong similarities with the molecular hydrogen emission from the giant inter-group shock structures in Stephan's Quintet. We use excitation diagrams to characterize the warm molecular gas, finding a high average surface mass of

5 M_{solar}/pc² and typical excitation temperatures of 150-170 K. This is likely to be a lower limit to the surface density because of limitations in the spectral coverage over most of the bridge, allowing only one excitation temperature component to be modeled. Emission is also seen in the galaxy disks, with the larger ringlike galaxy, UGC 12914, exhibiting exceedingly strong H2 lines which dominate other mid-IR line features. We investigate several possible warming mechanisms for the gas, including cosmic rays, magnetic reconnection, and shocks, with the latter seeming to be the most likely. The very powerful H2 luminosity in the Taffy bridge gas appears to be another example (like Stephan's Quintet) of how large H2 line luminosities, which dominate the mid-IR cooling, can be generated by high-speed encounters. In this case two counter-rotating interpenetrating disks may have helped in increase the kinetic energy available to heat the molecular gas in a post-shocked "Taffy" layer as the galaxies pull apart. Since the cooling time is so short in the warm H2 gas, shocks must be permeating the bridge region in order to continue to heat the molecular hydrogen. Collisions between gas-rich systems may be more common at high-redshift, and so the observations have implications for future IR missions which might be sensitive to rotational cooling lines of molecular hydrogen shifted into the far-IR.

335.28

Hα-FUV Flux Ratios of Local Volume Galaxies: Effects of Systematic Biases on Upper IMF Constraints Lent C. Johnson¹, D. R. Weisz¹, B. D. Johnson², E. D. Skillman³, LVL Team

¹University of Washington, ²Cambridge University, United Kingdom, ³University of Minnesota. Exhibit Hall

Recent observational evidence has shown that dwarf galaxies exhibit lower H α -FUV flux ratios than typical star-forming galaxies. While this fact has been interpreted as evidence for a variable upper IMF, these results are subject to systematics due to imperfect internal dust attenuation corrections and other biases. Using observations of 127 Local Volume star-forming galaxies derived from the LVL and SDSS datasets, we explore how different internal dust corrections and sample completeness can affect the resulting physical interpretation. We also examine the susceptibility of our H α -FUV ratio distribution and correlation analyses to biases that result from our choice of independent parameter (e.g., stellar mass, R-band surface brightness). We then apply our understanding of these factors to test the possibility that the observed ratio distribution could be the result of age effects. Using model star formation histories, we can explain the distribution of H α -FUV ratios without invoking variations in the upper IMF.

335.29

Sampling Studies Of Quasars, Radio-loud Galaxies, & Radio-quiet Galaxies -- Searching For The Cause Of Radio Emission

G. Coldwell¹, Amee Salois², I. Soechting³, M. Smith⁴

¹El Instituto de Ciencias Astronómicas, de la Tierra y del Espacio, Argentina, ²University of Arkansas, ³Oxford, United Kingdom, ⁴Cerro Tololo Inter-American Observatory, Chile. Exhibit Hall

Comparing the environments of Radio-Loud Galaxies, Radio-Quiet Galaxies, and Quasars offers an opportunity to study the evolution of these objects. Our samples have been carefully chosen from Data Release 7 of the Sloan Digital Sky Survey, which also includes samples studied in the FIRST survey, and have been cut to determine the best possible results. Our study includes three samples. The Quasar sample currently contains 69 objects, the Radio-Loud Galaxy (RLG) sample has 1,335 objects, and the Radio-Quiet Galaxy (RQG) sample contains 2,436 objects (any updates will be given at the meeting). A number of trims were made to produce (smaller) samples with characteristics suited for precise results. By comparing the environments of these three samples we will be able to see any similarities or differences between them. If similarities are detected it suggests that the central object has evolved according to 'nature' - in an isolated manner with little environmental feedback, which may or may not

have an effect on its evolution, as supposed by Coldwell et al. (2009). If differences are detected it suggests that the central object has evolved according to 'nurture' and that the environment may have played an important role in the development of their properties. We employ similar procedures used by Coldwell et al. (2009) in their study of blue and red AGNs. Upon the completion of an accurate sample, future work will be pursued studying a number of properties of the environments including studies of: the stellar masses, star formation rates, sersic morphologies, as well as densities and ages of the environments.

335.30

Distribution of Colors within Local (U)LIRGS

Kirsten Larson¹, D. Sanders¹, V. U¹

¹University of Hawaii, Institute for Astronomy.

Exhibit Hall

Large scale optical surveys have allowed for a detailed study of the color distribution of low- redshift galaxies. Red passively evolving galaxies and blue starforming galaxies populate two distinct regions on color magnitude diagrams. Luminous and ulta-luminous infrared galaxies ((U)LIRGs, LIR > 10^{11} L_{sol}) are galaxies where intense infrared emission is fueled by mergers, star formation and AGN and may represent a sample of galaxies in transition between the blue cloud and red sequence. We focus on a local sample of (U)LIRGs (z < 0.088) selected from the Revised Bright Galaxies Sample where we have sufficient resolution to study them in detail. Using imaging data from the Great Observatories All-sky LIRG Survey (GOALS), the (U)LIRGs' colors are compared to the blue cloud and red sequence of normal galaxies. We examine how the color of the (U)LIRGs change as a function of infrared luminosity and further investigate the origin of their colors by dividing the galaxies in to an inner 0-2 kpc, middle 2-5 kpc and outer regions. By using the changing color as an indication of star-formation, we discuss how star-formation and color change within the galaxies throughout the merging process.

335.31

Statistical Comparison of High- and Low-z ULIRGS Brian Connolly $^{\!\!1}$

¹University of Pennsylvania.

Exhibit Hall

In Farrah et al. (2009) we quantified the similarities and differences between low-redshift ULIRG spectra using two novel techniques. First, we computed a Bayes factor for every pair of spectra. Second, we visualized the resultant Bayes factors using network diagrams. In this work, we extend the analysis to high-redshift ULIRGS and compare the features of the network diagrams to those found for the low-redshift sample.

335.32

The Mass-Luminosity Relation of Galaxies in the Deep Lens Survey

Ami Choi¹, J. A. Tyson¹, I. P. Dell'Antonio², P. Gee¹, M. J. Jee¹, V. E. Margoniner³, S. J. Schmidt¹, D. M. Wittman¹

¹University of California, Davis, ²Brown University, ³California State University, Sacramento. Exhibit Hall

Characterization of the redshift-dependence of the total mass to light and stellar mass to total mass relationships is an important probe of galaxy evolution. Recent theoretical progress has been made using statistical models such as abundance matching, but observational studies have been primarily limited to galaxies at low redshifts or very massive galaxies at higher redshifts. We present results from the Deep Lens Survey using galaxy-galaxy weak lensing to directly constrain total galaxy masses over several decades of mass out to $z\sim0.7$. We investigate the correlation of the M/L with color and environment as well as the possibility of evolution with cosmological time.

335.33

Automatic Morphological Classification of Galaxies in SDSS/GALEX Based on Catalog Photometry Keaton Bell¹, S. Salim¹

¹Indiana University.

Exhibit Hall

Galaxies have been historically classified based on their morphologies, requiring visual identification of their defining structural features. This can be extremely time consuming and especially difficult for galaxies that are poorly resolved or at certain orientations. To quell these issues, a new automated proxy for visual morphological classification is needed. We utilized photometric magnitudes and angular size information from the Sloan Digital Sky Survey (SDSS) and Galaxy Evolution Explorer (GALEX) data releases to categorize galaxies at redshifts near z=0.1 as elliptical, lenticular, spiral, or irregular. A galaxy of interest has its catalog photometry corrected for redshift and is then compared to galaxies of known type from the Third Reference Catalog of Bright Galaxies (RC3) by a chi-squared goodness-of-fit analysis of their spectral energy distributions, radial light concentrations, ellipticities, and UV-to-optical size ratios. Testing this method on the RC3 galaxies themselves yielded probabilities that each of the four outcomes result from each source type. Overall, results are drawn from the correct sources a majority of the time, at 52% for ellipticals, 45% for lenticulars, 61% for spirals, and 71% for irregular galaxies. These likelihoods held up when the method was tested on galaxies near the target z~0.1 redshift with rough classifications available from the COSMOS survey. Finally, the method was applied to numerous galaxies at z~0.1 with established star formation rates and stellar masses to reveal connections between these values and galactic type. Most notably, lenticular galaxies, while of comparable mass to ellipticals, were shown to be undergoing more current star formation, and irregular galaxies were observed to contain generally less stellar material than spirals. This project was supported by the National Science Foundation as part of the Summer 2010 Astronomy REU Program at Indiana University.

335.34

Age and Metallicity of Merging Galaxies and Merger Remnants in the SDSS

Jennifer L. Nielsen¹, D. H. McIntosh¹, A. L. Cooper¹, T. Haines¹, A. McConnell¹, A. Gallazzi², A. Pasquali², F. C. van den Bosch³, H. J. Mo⁴, X. Yang⁵

¹UMKC, ²Max Planck Institute of Astrophysics, Germany, ³Yale, ⁴UMass, ⁵SAO, China. Exhibit Hall

We study the stellar ages and metallicities of major mergers and post-merger remnants among massive galaxies in the local universe. The ages and metallicities are excellent records of the star formation and chemical enrichment histories of galaxies, and major merging between comparable mass systems is postulated to be a central mechanism in explaining the assembly and growth of spheroids over cosmic time. Starting with a volume-limited (z LE 0.08) and stellar mass-limited (M GE 1e10 Msun) sample of 36,000 galaxies with SDSS spectra having median S/N > 20 we identified over 600 galaxies in pairs (mergers), and 100 individual systems (remnants), with tidal signatures associated with major merging activity. Using previously derived median-likelihood estimates of stellar metallicity, light-weighted age and stellar mass, we compare mergers and remnants to each other and to the underlying galaxy population. We confirm that the lower metallicity (Zstar < -0.1 Zsun) population has a higher fraction of isolated disturbed galaxies (remnants) compared to the majority of galaxies with typical stellar metal abundances (> -0.1 Zsun). Comparing mergers and remnants, we find that the remnant population has a higher percentage of low metallicity members than does the merger population. We further explore the stellar metallicity distributions of galaxies involved in spiral-spiral, spiral-elliptical and
elliptical-elliptical mergers. Last, we find that remnants have younger light-weighted ages on average than either galaxies involved in ongoing major interactions or non-merging systems. This result connects evidence of recent star formation with visible tidal signatures as expected in the aftermath of a gas-rich major merger.

335.35

The Role of Active Galactic Nuclei in the Major Merging Process

Andrew L. Cooper¹, D. H. McIntosh¹, A. McConnell¹, J. L. Nielsen¹, F. C. van den Bosch², H. J. Mo³, A. Pasquali⁴, X. Yang⁵

¹University of Missouri Kansas City, ²Yale University, ³University of Massachusetts, ⁴MPIA, Germany, ⁵SAO, China.

Exhibit Hall

We investigate the AGN activity of major mergers and post-merger remnants among massive galaxies in the local universe. A merger-fueled AGN and its subsequent quenching of star formation is postulated to be a central mechanism in explaining the formation and growth of the red and dead spheroid galaxy population over cosmic time. Starting with a volume-limited (z<0.08) and stellar mass-limited (M_{star} > 1e10 M_{sun}) sample of 32,500 emission-line galaxies from the SDSS, we identified over 900 galaxy pairs (mergers), and 100 individual systems (remnants), with tidal signatures associated with major merging activity. Using nebular emission line data based on SDSS fiber spectra from the MPA-JHU Emission Line Analysis, and employing a variety of emission-line flux ratio diagnostics that allow us to separate our sample into HII, AGN (both Seyferts and LINERs) and composite spectral types, we compare mergers and remnants to each other and to the non-merging galaxy population. At our mass cut, we note that galaxies that emit strong emission lines (S/N>3) never have purely star-forming central spectra as found in lower-mass emission-line systems. We find that more than half of the mergers and remnants in our sample have measureable AGN activity in their central spectra; at least 50% of each type are LINERs. Our results indicate that AGN activity is common among high-mass mergers, but with no apparent difference in activity strength relative to non-merging systems.

335.36

Pinpointing Counterparts to Submillimeter Galaxies in the Aztec/Cosmos Field Matthew Wahl¹, K. Sheth²

¹Stony Brook University, ²National Radio Astronomy Observatory.

Exhibit Hall

In the last decade, the sub-millimeter field has been opened up and advancing. After SCUBA detected the first two sub-millimeter galaxies (SMGs), follow up observation's revealed hundreds more. Although the number of SMGs continues to grow, our knowledge of SMGs is still based upon roughly 50% of the population. Without accurate positional information of these SMGs, that percentage will remain mostly unchanged. By using CARMA, we were able to generate accurate positional information (< .3 arcsec) on 3 SMGs. With this information, it is possible to accurately identify, the radio and optical counterparts to these SMGs, which is critical to figuring out their redshift.

335.37

The Largest z>3 Sample of X-ray Quasars: COSMOS

Francesca M. Civano¹, M. Brusa², M. Elvis¹, A. Comastri³, M. Salvato⁴, COSMOS Collaboration ¹Harvard Smithsonian Center for Astrophysics, ²MPE, Germany, ³INAF-Bologna, Italy, ⁴IPP, Germany. Exhibit Hall

Multiwavelength identification campaigns from medium deep and deep X-ray surveys with XMM and Chandra have opened a new perspective in the study of the high-redshift (z>3) AGN population. For the first time, were able to provide sizable samples of quasars with luminosities above logLx=43.5. However,

samples sizes have been quite limited, limiting the conclusions that can be drawn. We present the properties of the largest sample (61 sources) of X-ray selected z>3 AGNs, from the Chandra COSMOS survey. This sample defines the space density and evolution of the z>3 X-ray selected AGN population. The z>4 population is sampled usefully, and the z>5 population is beginning to emerge. The results are compared with predictions from XRB synthesis models and semianalythic models of galaxy formation. Some models are clearly excluded.

335.38

A Far-ir Characterization Of 24 Micron Selected Galaxies At 0 < Z < 2.5 Using Stacking At 70 Microns And 160 Microns In The Cosmos Field

Nicholas Lee¹, E. Le Floc'h¹, D. B. Sanders¹ ¹Institute for Astronomy, University of Hawaii.

Exhibit Hall

We present a study of the average properties of luminous infrared galaxies detected directly at 24 μ m in the COSMOS field using a median stacking analysis at 70 μ m and 160 μ m. Over 35000 sources spanning 0<z<3 and 0.06 mJy<S₂₄< 3.0 mJy are stacked, divided into bins of both photometric redshift and 24 μ m flux. We find no correlation of S₇₀/S₂₄ flux density ratio with S₂₄, but find that galaxies with higher S₂₄ have a lower S₁₆₀/S₂₄ flux density ratio. These observed ratios suggest that 24 μ m selected galaxies have warmer SEDs at higher mid-IR fluxes, and therefore have a possible higher fraction of AGN. Comparisons of the average S₇₀/S₂₄ and S₁₆₀/S₂₄ colors with various empirical templates and theoretical models show that the galaxies detected at 24 μ m are consistent with "normal" star-forming galaxies and warm mid-IR galaxies such as Mrk 231, but inconsistent with heavily obscured galaxies such as Arp 220. We perform a chi-squared analysis to determine best fit galactic model SEDs and total IR luminosities for each of our bins. A comparison of our results to previous methods of estimating L_{IR} shows considerable agreement over the full redshift range, except for the brightest S₂₄ sources, where previous methods overpredict the bolometric IR luminosity at high redshift, most likely due to their warmer dust SED. We present a table that can be used as a more accurate and robust method for estimating bolometric infrared luminosity from 24 μ m flux densities.

335.39

Inverse-compton Ghosts and Double-lobed Radio Sources in the X-ray Sky

Philip Mocz¹, A. Fabian², K. Blundell³

¹Harvard University, ²Institute of Astronomy, United Kingdom, ³Astrophysics, University of Oxford, United Kingdom.

Exhibit Hall

In this study we predict the total distributions of powerful (FR II) active double-lobed radio galaxies and ghost sources, and their observable distribution in the X-ray sky. We develop an analytic model for the evolution of the lobe emission at radio and X-ray energies. During jet activity, a double radio source emits synchrotron radiation in the radio and X-ray emission due to inverse-Compton (IC) upscattering by gamma~10³ electrons of the cosmic microwave background. After the jets switch off, the radio luminosity (due to higher gamma electrons) falls faster than the X-ray luminosity and for some time the source appears as an IC ghost of a radio galaxy before becoming completely undetectable in the X-ray. With our model, for one set of typical parameters, we predict radio lobes occupy a volume fraction of the universe of 0.01, 0.03, 0.3 at z = 2 (during the quasar era) of the filamentary structures in which they are situated, for typical jet lifetimes $5*10^7$ yr, 10^8 yr, $5*10^8$ yr; however since the inferred abundance of sources depends on how quickly they fall below the radio flux limit the volume filling factor is found to be a strong function of radio galaxy properties such as energy index and minimum gamma factor of injected particles, the latter not well constrained by observations. We test the

predicted number density of sources against the Chandra X-ray Deep Field North survey and also find the contribution to the unresolved cosmic X-ray background by the lobes of radio galaxies. 10-30 per cent of observable double-lobed structures in the X-ray are predicted to be IC ghosts. The derived X-ray luminosity function of our synthetic population shows that double-lobed sources have higher space densities than X-ray clusters at redshifts z > 2 and X-ray luminosities above 10⁴⁴ erg s⁻¹

335.40

Disk Galaxy Assembly: Evolution of the Stellar Mass Tully-Fisher Relation to z~1.3

Sarah Miller¹, K. Bundy², M. Sullivan¹, R. Ellis³, T. Treu⁴

¹University of Oxford, United Kingdom, ²UC Berkeley, ³Caltech, ⁴UC Santa Barbara. Exhibit Hall

We present new measures of the 0.2 < z < 1.3 evolution of scaling relations between stellar mass, magnitude, rotational velocity, and disk size for a diverse sample of ~140 disk-like galaxies using deep spectra from the DEIMOS instrument on the Keck II 10 m telescope, combined with stellar masses derived from multi-color HST ACS and ground-based K-band imaging. An unique feature of our survey is our extended spectroscopic integrations (6-8 hours in most cases), which have led to significant improvements in determining the rotational velocities compared to previous work. Over 80% of our rotation curves are traced to their flattening radii, and we model the HST resolved bulge and disk components of each galaxy in order to improve the accuracy of our velocity measurements. From the context of popular assembly models, we analyze and discuss the observed trends in our scaling relations in order to construct a clearer picture of the intermediate redshift evolution of disk galaxies.

335.41

AKARI and Spitzer Infrared Diagnostics of Luminous Infrared Galaxies

Jason Chu¹, L. J. Kewley¹, D. S. N. Rupke¹, H. Inami²

¹University of Hawaii, Institute for Astronomy, ²Spitzer Science Center, California Institute of Technology. Exhibit Hall

We present AKARI near-infrared (NIR) and Spitzer mid-infrared (MIR) spectroscopy of both luminous infrared galaxies (LIRGs) and ultra luminous infrared galaxies (ULIRGs) from the Revised Bright Galaxy Sample and the 1 Jy sample, respectively. Luminous infrared galaxies emit more of their bolometric luminosity in the infrared (8-1000 microns) than in all other parts of the spectrum combined. It appears that the infrared luminosity originates from a combination of starburst and active galactic nucleus (AGN) (cf. Sanders & Mirabel 1996 and references therein). For the first time we combine emission line fluxes in both 2.5-5 micron data from AKARI with 5-35 micron data from Spitzer to derive new infrared diagnostic diagrams that can distinguish between starburst and AGN activity in heavily obscured (U)LIRGs. Previous attempts at classifying these galaxies in the optical regime have proven to be very difficult due to the heavy dust extinction from buried AGNs. However since infrared radiation is affected much less by dust than in the optical, we show that the infrared emission line diagnostic [Ne III]/[Ne II] vs. [O IV]/Br-alpha appears most promising in separating starburst-driven ULIRGs and AGN-driven ULIRGs. In addition the diagnostic [Ne III]/[Ne II] vs. [S III]/Br-alpha also appears to be moderately effective in separating ULIRGs driven by starbursts and AGNs, while the [NeIII]/[Ne II] vs. [S IV]/Br-alpha ratio does a relatively poor job. These results were then compared to theoretical models generated by the Starburst99 and Mappings codes.

335.42 Narrowband Lyman Continuum Imaging of Galaxies at z=2.85 Robin E. Mostardi¹, A. E. Shapley¹

¹UCLA.

Exhibit Hall

Lyman-continuum (LyC) radiation from galaxies appears to constitute an increasingly significant component of the ionizing background at redshifts beyond $z \sim 3$, and almost certainly dominates the radiation field at the epoch of H I reionization. Therefore, estimating the contribution to the ionizing background from galaxies represents a fundamental goal for observational cosmology. We have acquired deep LRIS narrowband imaging of the Q1549+1933 field with a filter tuned to the wavelength range just below the Lyman limit (3420 A) of a redshift spike of galaxies at z=2.85. The field contains 49 Lyman Break Galaxies (LBGs) at $z \ge 2.85$, and 199 narrow-band selected Lyman Alpha Emitters (LAEs) (73 spectroscopically confirmed at $z^2.85$). We present the photometry of 24 objects (19 LAEs, 5 LBGs) with robust narrowband detections and a multiwavelength analysis of the intensity and spatial distribution of the escaping ionizing radiation.

335.43

First Spectroscopic Measurements Of [OIII] Emission From Field Lyman-alpha Selected Galaxies At z \sim 3.1

Emily McLinden¹, S. L. Finkelstein², J. E. Rhoads¹, S. Malhotra¹, P. Hibon¹, M. Richardson¹ ¹School of Earth and Space Exploration, Arizona State University, ²George P. and Cynthia Woods Mitchell Institute for Fundamental Physics and Astronomy, Department of Physics and Astronomy, Texas A&M University.

Exhibit Hall

We present the first spectroscopic measurements of the [OIII] 5007 Angstrom line in two z ~ 3.1 Lymanalpha emitting galaxies (LAEs) using the new near-infrared instrument LUCIFER1 on the 8.4m Large Binocular Telescope (LBT). This work includes also the optical imaging and spectroscopic observations used to identify these Ly-alpha emitting galaxies. These [OIII] measurements represent the first direct constraints on the strength of the [OIII] line in high-redshift LAEs, where we find [OIII] line fluxes of ~ 7 - $36 \times 10^{-17} \text{ erg/s/cm}^2$ in two z ~ 3.1 LAEs. These lines are strong enough to dominate broad-band flux measurements that include the line (in this case, K_s band photometry). Spectral energy distribution fits that do not account for the lines would therefore overestimate the 4000 Angstrom (and/or Balmer) break strength in such galaxies, and hence also the ages and stellar masses of such high-z galaxies. Additionally, we have used the [OIII] line to measure accurate systemic redshifts for these two galaxies. In doing so we have uncovered a velocity offset between the [OIII] and Ly-alpha lines in both LAEs, with the Ly-alpha line peaking 343 and 126 km/s redward of the systemic velocity. These velocity offsets imply that there are powerful outflows in high-redshift LAEs. These types of offsets can also ease the transmission of Ly-alpha photons through the intergalactic medium around the galaxies. This work was supported by NSF grant AST-0808165.

335.44

Interpreting the Evolution of the Size-Luminosity Relation for Disk Galaxies from Redshift 1 to the Present

Alyson Brooks¹

¹*California Institute of Technology.*

Exhibit Hall

A sample of very high resolution cosmological disk galaxy simulations is used to investigate the evolution of galaxy disk sizes back to redshift 1 within the ACDM cosmology. Artificial images in the rest frame B

band are generated, allowing for a measurement of disk scale lengths using surface brightness profiles as observations would, and avoiding any assumption that light must follow mass as previous models have assumed. We demonstrate that these simulated disks are an excellent match to the observed magnitude - size relation for both local disks, and for disks at z=1 in the magnitude/mass range of overlap. We disentangle the evolution seen in the population as a whole from the evolution of individual disk galaxies. In agreement with observations, our simulated disks undergo roughly 1.5 magnitudes/arcsec² of surface brightness dimming since z=1. The disks grow in such a way as to stay on roughly the same stellar mass - size relation with time. Finally, due to an evolving stellar mass - SFR relation, a galaxy at a given stellar mass (or size) at z=1 will reside in a more massive halo and have a higher SFR, and thus a higher luminosity, than a counterpart of the same stellar mass at z=0.

335.45

Deep Grism Spectroscopy of High Redshift Galaxies with the HST GRAPES and PEARS Surveys James E. Rhoads¹, S. Malhotra¹, N. Pirzkal², GRAPES team, PEARS team

¹Arizona State Univ., ²Space Telescope Science Institute.

Exhibit Hall

We have obtained the deepest slitless spectroscopic samples ever using the Hubble Space Telescope's Advanced Camera for Surveys, in two related projects, the "Grism ACS Program for Extragalactic Science" (GRAPES) and "Probing Evolution and Reionization Spectroscopically" (PEARS). In combination, these two programs obtained deep public spectroscopy of about 100 square arcminutes in the GOODS north and south fields. We are using these data to study galaxy evolution over a wide range of cosmic history. We are able to spectroscopically confirm Lyman break galaxies from redshift 4 to 6.5, down to AB magnitudes fainter than i=27.5. We use these samples to study a range of galaxy properties, including spatial clustering, Lyman alpha emitter fraction, and spatial extent of Lyman alpha emission.

335.46

Extended UV Disks in Low-Mass E/SO Galaxies and Their Relation to Disk Building

Amanda J. Moffett¹, S. J. Kannappan¹, A. J. Baker², S. Laine³

¹University of North Carolina at Chapel Hill, ²Rutgers, the State University of New Jersey, ³Spitzer Science Center.

Exhibit Hall

We investigate the frequency of XUV disks in a sample of E/S0s with stellar masses primarily below ~4 x 10^{10} solar masses, located on both the red and blue sequences in color versus stellar mass space. We examine evidence that Type 1 XUV disks in certain regimes may be associated with weak or inefficient outer-disk star formation, as opposed to star formation capable of driving substantial disk growth. We also explore alternative indicators of strong disk building in E/S0s.

335.47

Axis Ratio Evolution of Red and Blue Galaxy Populations Since z=1

Cory R. Wagner¹, D. H. McIntosh¹, A. van der Wel²

¹University of Missouri-Kansas City, ²Max-Planck Institute for Astronomy, Germany. Exhibit Hall

We study the projected axis ratio distributions of red and blue galaxies as a function of stellar mass and redshift. At low redshift, the preponderance of high-mass, non-star-forming galaxies with spheroidal axis ratios (b/a>0.6) is cited as strong evidence for their major-merger origin; similar studies for star formers are lacking. The evolution of massive red galaxy shapes provides an important test for major merging being their primary growth channel. Starting with a stellar mass cut of M>1e10 M_{sun}, we select 2500 galaxies with HST/ACS imaging and redshifts z>0.46 from the GEMS (Galaxy Evolution From Morphology and SEDs) and STAGES (Space Telescope A901/902 Galaxy Evolution Survey) surveys, and 4500 SDSS

(z^{-0}) galaxies. Using (U-V) color, we compare the red and blue fraction of b/a>0.6 galaxies in the local universe. We find that the fraction of red spheroid galaxies increases steadily from 40% at the bimodal mass cut (3e10 M_{sun}) to 70% above 1e11 M_{sun}, consistent with the trends for spectroscopically-selected quiescent galaxies. Moreover, the average axis ratios of blue galaxies increases with increasing stellar mass in a similar manner as for red galaxies. Using a passively-evolving (U-V) color-mass cut to define red galaxies at z>0, we find no evolution in the fraction of red spheroids at moderate and high masses, implying that most additions to the massive red population at different cosmic epochs are from major mergers.

335.48

Nuclear Star Forming Ring of the Milky Way: Simulations

Sungsoo S. Kim¹, T. R. Saitoh², M. Jeon³, D. Merritt⁴, D. F. Figer⁴, K. Wada⁵ ¹Kyung Hee University, Korea, Republic of, ²National Astronomical Observatory of Japan, Japan, ³University of Texas, ⁴Rochester Institute of Technology, ⁵Kagoshima University, Japan. Exhibit Hall

We present hydrodynamic simulations of gas clouds in the central kpc region of the Milky Way that is modeled with a three-dimensional bar potential. Our simulations consider realistic gas cooling and heating, star formation, and supernova feedback. As found in previous two-dimensional simulations, gas clouds undergo an abrupt loss of angular momentum at the cusps of the innermost closed, elongated orbits along the bar (X₁ orbits), plunge to a new family of orbits much deeper in the potential (X₂ orbits), and accumulate there forming the Central Molecular Zone (CMZ). We find that the gas clouds in the X₂ orbits can reach high enough densities to form stars, and our star formation rates are consistent with observationally inferred SFR values, a fraction of $0.1 \text{ M}_{\odot} \text{ yr}^{-1}$, obtained by Yusef-Zadeh et al. Star formation in our simulations takes place mostly in the outermost X₂ orbits with a radius of ~200 pc, and this suggests that the star formation observed in the CMZ may be a mini version the of nuclear star forming ring seen in some external disk galaxies.

335.49

Counting Diamonds in the Rings -- Ring Fragmentation in Collisional Ring Galaxies

Anna Saburova¹, D. Bizyaev², A. Moiseev³, E. Vorobyov⁴

¹SAI, Russian Federation, ²APO/NMSU, ³SAO RAS, Russian Federation, ⁴UVO, SFU, Canada. Exhibit Hall

Fragmentation of the star-forming rings in collisional ring galaxies is considered from the standpoint of traditional thin-gaseous-disk instability criteria. The number of bright fragments ("diamonds" in the rings on a kiloparsec-size scale) depends on the dominant mechanism of gas fragmentation in the ring. We consider two mechanisms: that of Elmegreen and that of Safronov-Toomre-Kennicutt (STF, applied to both density wave-induced and material rings) and compare the theoretically predicted number of "diamonds" with observations.

We employ kinematical and photometrical parameters obtained for a sample of six collisional rings which were observed with the multi-mode imager/spectrograph/IFP SCORPIO at the 6-m telescope BTA (Russia). We find that the pure-gaseous-disk instability criterion (i.e., STF) predicts the correct number of the fragments in the rings.

Search for z~6.96 Lyman-alpha Emitters with IMACS/Magellan in the COSMOS Field Pascale Hibon 1

¹ASU.

Exhibit Hall

Searching high redshift galaxies is one of the most active fields of observational cosmology and is essential to the characterization and understanding of the formation and evolution of the galaxies. Galaxies at redshift 6 are routinely found. Detection of $z\sim7$ galaxies is however still rare. From z=6.5 to z=7 light dimming due to luminosity distance is 17% and the age of the Universe varies by 172 Myr. At these redshift, the Universe is thought to be undergoing re-ionization. One tracer of high z galaxies is the Ly-alpha line which can be detected through Narrow Band (NB) imaging surveys. The Luminosity Function (LF) of high z LAEs is one of the few observables of the re-ionization epoch accessible to date with 8-10m telescopes. The determination of the Ly-alpha LF at high z is actively pursued by several groups. The evolution of the Ly-alpha LF involves both the evolution of the re-ionization state of the Universe and of the Ly-alpha population which can also be traced by the evolution of the UVLF. This evolution with redshift allows us to constrain the evolution of LAEs and their role in re-ionizing the Universe at the end of the Dark Ages. Results on the evolution of both UVLF and LAEs LF at z~7 are still limited and occasionally contradictory. We have carried out a 28 hours NB (9680A) imaging program, targeting z~7 LAEs, using the IMACS/Magellan instrument. The data were taken over 2 years. We reached a detection limit of 8.9e-18 erg/s/cm2. From these observations, we have derived a photometric sample of z~7 LAEs candidates. After careful evaluation of possible sources of contamination, and accounting for cosmic variance, we inferred the LF at z~7 LAEs and constrain the LFs produced by different existing models. These results will need to be confirmed by spectroscopic followup.

335.51

The Spitzer Public Legacy Survey of the 1 square degree UKIDSS Ultra Deep Survey

Minjin Kim¹, J. S. Dunlop², C. J. Lonsdale¹, D. Farrah³, M. Lacy¹, M. Sun⁴, SpUDS team ¹National Radio Astronomy Observatory, ²University of Edinburgh, United Kingdom, ³University of Sussex, United Kingdom, ⁴University of Virginia.

Exhibit Hall

The Spitzer Public Legacy Survey of the UKIDSS Ultra Deep Survey (SpUDS) has been carried out with four IRAC bands and one MIPS band (24um). SpUDS surveys 1 square degree of the UDS field, that has been covered by one of the deepest near IR surveys and by various multiwavelength observations from X-ray to radio (XMM, GALEX, Subaru, SCUBA, VLA). We present a summary of the photometric data including number counts derived at 3.6-24 microns. In conjunction with extensive multiwavelengh data, we are able to show the multiwavelenght color distribution of MIR sources, and how different SED types contribute to the number counts.

336 Pulsars, Neutron Stars Poster Session *Exhibit Hall*

336.01

Fitting Pulsar Observations To The Spectrum Of The Emission From A Faster-than-light Source Andrea C. Schmidt¹, J. Singleton², H. Ardavan³, A. Ardavan⁴, J. Middleditch⁵

¹LANL/UNM, ²National High Magnetic Field Laboratory, ³University of Cambridge, United Kingdom, ⁴University of Oxford, United Kingdom, ⁵LANL.

Exhibit Hall

In two recent papers we have compared the multiwavelength observations of nine broadband pulsars with the radiation spectrum generated by a polarization current that rotates faster than light *in vacuo* and found that this single emission process accounts quantitatively for the spectrum of each pulsar over 16-18 orders of magnitude of frequency. Here we extend this work to include data from millisecond Gamma-ray pulsars detected by the Fermi Large Area Telescope (LAT). In order to describe broadband pulsar data using the superluminal model, the two most important parameters are the pulsar's known rotational frequency and a resonant frequency of the atmosphere around where the emission occurs. It is natural to ascribe the latter to the plasma frequency. All of the pulsars studied exhibit one further feature: an enhancement of the emission at higher frequencies. This will occur if the permittivity of the pulsar atmosphere has a second resonant frequency; we attribute this to cyclotron resonance of the electrons in the pulsar's magnetic field. Using these three parameters, obtained by fitting the data for the LAT millisecond pulsars, we have extracted values for the electron density and the magnetic field at the emitting region and derived some systematic properties of their plasma atmospheres. The results reported here are model-independent in that the only global property of the magnetospheric structure invoked is its quasi-steady time dependence, a property that follows unambiguously from the observational data and implies that a current distribution with a superluminally rotating pattern outside the light cylinder is responsible for the unique features of pulsar emission.

336.02

Radio Pulse Profiles and Polarization Modeling in the Outer Magnetosphere

Helen A. Craig¹, R. W. Romani¹, S. Johnston²

¹Stanford University, ²Australia Telescope National Facility, Australia. Exhibit Hall

Radio polarization observations of rotation-powered pulsars can provide valuable constraints on the spin geometry. Conventionally the analytic rotating vector model (RVM) is fit to the position angle sweep to constrain the magnetic inclination angle (α) and viewing angle (ζ). Such fits are particularly valuable for interpreting the pulsed radiation at high energy. However, these fits are strictly relevant only to point dipoles. We have used 3-D models of the magnetospheric field structure to compute radio light curves and polarization sweeps when the emission lies at an altitude that is a large fraction of the light cylinder. The results agree with the RVM at altitudes small compared to the light cylinder and the shifts follow the general trends derived analytically by Blaskiewicz et al (1991), albeit with a larger amplitude. At high fractions of the light cylinder, as might be relevant to millisecond pulsars, the perturbations to the RVM model are large and complex. These models can be particularly useful to understanding Fermi LAT data; we show some example fits to the radio/gamma-ray data.

336.03 Gradual Mode Evolution in PSR B0943+10 Isaac Backus¹

¹University of Vermont.

Exhibit Hall

40 years after the discovery of pulsars, their emission mechanisms are still poorly understood. A problem which still lacks explanation is that of moding: it is observed that the average pulse profile of many pulsars switches between two or more discrete modes. We present an 8 hr observation of the well known drifting and moding pulsar B0943+10. While the pulsar has two discrete modes of emission, and switches between modes in less than a pulse, there is a gradual evolution of its properties within one of the modes: the linear polarization increases; the drift rate and the average pulse profile change with the same characteristic time. Under the subbeam carousel model, we infer from these dynamics that the ExB drift velocity may gradually vary during one mode which may imply a change in temperature at the polar cap.

336.04

Constraints On Electron Injection And Transport From Modeling Of The Pulsar Wind Nebula HESS J1825-137

Adam Van Etten¹, R. W. Romani¹

¹Stanford University.

Exhibit Hall

The pulsar wind nebula associated with PSR J1826-1334, HESS J1825-137, is a bright very high energy source with an angular extent of ~1 degree and spatially-resolved spectroscopic TeV measurements. The gamma-ray spectral index is observed to soften with increasing distance from the pulsar, likely the result of cooling losses as electrons traverse the nebula. Yet while the extended nebula stemming from PSR J1826-1334 has been well studied at TeV energies, only the core of the pulsar wind nebula has been studied in detail at longer wavelengths. We describe analysis of X-ray data of the extended nebula and 3-D time-dependent spectral energy distribution modeling of this source, with emphasis on the spatial variations within HESS J1825-137. We find that the multi-wavelength data already places significant constraints on the electron injection, transport, and cooling.

336.05

Improving Recent Large-Scale Pulsar Surveys

Rogerio Fernando Cardoso¹, S. Ransom²

¹University of Wisconsin-Madison, ²National Radio Astronomy Observatory. Exhibit Hall

Pulsars are unique in that they act as celestial laboratories for precise tests of gravity and other extreme physics (Kramer 2004). There are approximately 2000 known pulsars today, which is less than ten percent of pulsars in the Milky Way according to theoretical models (Lorimer 2004). Out of these 2000 known pulsars, approximately ten percent are known millisecond pulsars, objects used for their period stability for detailed physics tests and searches for gravitational radiation (Lorimer 2008). As the field and instrumentation progress, pulsar astronomers attempt to overcome observational biases and detect new pulsars, consequently discovering new millisecond pulsars. We attempt to improve large scale pulsar surveys by examining three recent pulsar surveys. The first, the Green Bank Telescope 350MHz Drift Scan, a low frequency isotropic survey of the northern sky, has yielded a large number of candidates that were visually inspected and identified, resulting in over 34.000 thousands candidates viewed, dozens of detections of known pulsars, and the discovery of a new low-flux pulsar, PSRJ1911+22. The second, the PALFA survey, is a high frequency survey of the galactic plane with the

Arecibo telescope. We created a processing pipeline for the PALFA survey at the National Radio Astronomy Observatory in Charlottesville- VA, in addition to making needed modifications upon advice from the PALFA consortium. The third survey examined is a new GBT 820MHz survey devoted to find new millisecond pulsars by observing the target-rich environment of unidentified sources in the FERMI LAT catalogue. By approaching these three pulsar surveys at different stages, we seek to improve the success rates of large scale surveys, and hence the possibility for ground-breaking work in both basic physics and astrophysics.

336.06

Toward a Second Fermi LAT Pulsar Catalog

J. Eric Grove¹, P. Saz Parkinson², D. A. Smith³

¹Naval Research Lab, ²University of California Santa Cruz, ³Universite de Bordeaux, CENBG, France. Exhibit Hall

The Fermi Large Area Telescope (LAT) has proved to be a remarkably powerful tool for pulsar discovery. The First Fermi LAT Pulsar Catalog (Abdo et al. 2009, ApJSS) reported the detection of gamma-ray pulsations from 46 pulsars in data from the first six months of the mission. About two thirds were discovered using timing solutions derived from monitoring radio pulsars, including both young pulsars and millisecond pulsars. The remaining third were previously unknown pulsars, discovered by searching for pulsed signals at the locations of gamma-ray sources seen with the LAT. The number of detected gamma-ray pulsars has approximately doubled since then, and a second pulsar catalog is being prepared. We summarize the general properties of and key conclusions from the population of gammaray pulsars.

336.07

XMM-Newton Observations of Fermi-LAT Gamma-Ray Sources

Michael Thomas Wolff¹, K. S. Wood¹, P. S. Ray¹, J. E. Grove¹, E. C. Ferrara², C. C. Cheung³, LAT Collaboration

¹NRL, ²NASA-GSFC/UMCP, ³NRC.

Exhibit Hall

We continue our campaign of multi-wavelength observations of Fermi-LAT gamma-ray sources at high galactic latitude utilizing the XMM-Newton EPIC-pn (PN) and MOS instruments. The fields of view of both the PN and MOS instruments are approximately 30 arcmin in diameter and yield arc second positional accuracy for significant X-ray point sources. Thus, for Fermi-LAT sources that are not associated with a known source in another energy band, XMM-Newton can efficiently search for possible associated X-ray sources in the several-arc-minute elliptical error regions of the Fermi-LAT sources. We report here on observations of 1FGLJ2001.1+4351, 1FGLJ0614.1-3328 (=PSRJ0614-33), and 1FGLJ2214.8+3002 (=PSRJ2214.7+30). For 1FGLJ2001.1+4351, the XMM-Newton observations reveal a strong X-ray source inside the Fermi-LAT error ellipse with a power law spectrum and a flux of order 5E-12 ergs/cm²/s (0.5-8 keV). In the case of 1FGLJ0614.1-3328 (=PSRJ0614-33) we discuss both new XMM-Newton observations obtained in 2010 and archival observations obtained in 2001. In the case of PSRJ2214.7+30 (=1FGLJ2214.8+3002) we report on the analysis of PN timing mode data for the X-ray point-source at the pulsar position and we characterize its spectral properties as measured by the MOS instruments.

This work is supported by NASA XMM-Newton Guest Investigator Program and the Office of Naval Research.

Search for the X-ray Counterpart of Pulsars with GeV Emissions

Richard Aaron Knoche¹, T. Sakamoto²

¹James Madison University, ²Goddard Space Flight Center/University of Maryland Baltimore County. Exhibit Hall

Motivated by a search to identify the x-ray counterpart of GeV emissions from pulsars detected by Femi-LAT, we have analyzed over forty pulsar observations from various x-ray missions. Among these missions are BeppoSax, SWIFT, and Chandra. Through our analysis we have been able to identify the X-ray counterpart, estimate the X-ray flux, and calculate the x-ray photon index for much of our sample. We have investigated the correlations between observed properties such as fluxes and photon indices in Xray and GeV, as well as pulsar parameters such as the magnetic field strength, the rate of rotational energy loss and the spin down age for all of our sample in order to characterize each pulsar further.

336.09

Analysis of the Timing and Emission Properties of RRAT J0627+16

Deborah Schmidt¹, J. Deneva², D. Mitra³, J. Rankin⁴

¹Franklin & Marshall College, ²NAIC (Cornell University), ³National Centre for Radio Astrophysics, TIFR, India, ⁴University of Vermont.

Exhibit Hall

The nature of rotating radio transients (RRATs) remains one of the greatest mysteries in the field of pulsar astronomy today. Whether RRATs have a similar emission mechanism as pulsars or emit via an entirely different method can only be determined by analyzing the pulsed emission and polarization characteristics of various known RRATs over a range of frequencies in the radio spectrum. One such example, J0627+16 was first observed as part of the PALFA survey of the galactic plane in 2006 as nine single pulses with a fitted period of 2.180 s and DM of 125 pc/cm³. Subsequently, seven more observations at both 327 MHz and 1400 MHz were taken using the Arecibo telescope. These observations were each individually searched for single pulses using a friends-of-friends algorithm. The TEMPO timing software was used to fit a more accurate period, position, and dispersion measure using the new data. Furthermore, two average pulse profiles at both 327 MHz and 1400 MHz were created in order to attempt radius-to-frequency mapping on J0627+16, a process which might provide insight into the connection between the emission mechanisms of RRATs and pulsars. Preliminary results show that this is possible on J0627+16, although more observations and suitable polarization data is necessary to provide additional evidence to the correlation.

336.10

A Search For Evidence of Pulsar Origins Through Astrometry and Polarimetry

Megan Force¹, J. Rankin¹

¹University of Vermont.

Exhibit Hall

We investigate the relationship between the rotational and velocity vectors in pulsars, in order to determine the direction of the natal "kick" delivered to the pulsar during the supernova of a massive parent star. Absolute polarization angles are compared with published values for the proper motion angles of pulsars, with differences suggesting parallel or perpendicular offsets. The determination of the orientations of particular polarization modes is essential in the identification of vector alignments, and hence the explanation of the observed high pulsar velocities.

On the Peculiar Properties and Geometric Regularity of Lyne & Manchester's ``Partial Cone'' Pulsars Joanna M. Rankin¹, D. Mitra²

¹Univ. of Vermont, ²National Centre for Radio Astrophysics, India. Exhibit Hall

Lyne & Manchester (1988) identified a group of some 50 pulsars they called ``partial cones'' which they found difficult to classify and interpret. They were notable for their asymmetric average profiles and asymmetric polarization position-angle (PPA) traverses, wherein the steepest gradient (SG) point fell toward one edge of the total intensity profile. Over the last two decades, this population of pulsars has raised cautions regarding the core/cone model of the radio pulsar-emission beam which implies a high degree of order, symmetry and geometric regularity.

We reinvestigate this population ``partial cone" pulsars on the basis of new single pulse polarimetric observations of 39 of them, observed with the Giant Meterwave Radio Telescope in India and the Arecibo Observatory in Puerto Rico. These highly sensitive observations help us to establish that most of these ``partial cones'' exhibit a core/cone structure just as did the ``normal'' pulsars studied earlier. In short, we find that many of these ``partial cones'' are partial in the sense that the emission above different areas of their polar caps can be (highly) asymmetric. However, when studied closely we find that their emission geometries are overall identical to core/double cone structure encountered earlier----that is, with specific conal dimensions scaling as the polar cap size.

Further, the ``partial cone'' population includes a number of stars with conal single profiles that are asymmetric at meter wavelengths for unknown reasons (e.g., like those of B0809+74 or B0943+10). We find that aberration-retardation appears to play a significant role in distorting the core/cone emission-beam structure in rapidly

rotating pulsars. We also find several additional examples of highly polarized pre- and postcursor features that do not appear to be generated at low altitude but rather at high altitude, far from the usual polar fluxtube emission sites of the core and conal radiation.

336.12

Pulsar Search Results from the Arecibo Remote Command Center

Kevin Stovall¹, F. A. Jenet², A. Ford², R. Miller², A. Garcia², J. Rivera², L. Dartez², F. Ceballos², J. Martinez², K. Kayal², M. Flores², S. Leake², J. Hinojosa², A. Zermeno², A. Miller², X. Siemens³, J. Creighton³, J. Clayton³, D. Day³, C. Biwer³, PALFA Consortium, A. Mata²

¹University of Texas at San Antonio, ²University of Texas at Brownsville, ³University of Wisconsin-Milwaukee.

Exhibit Hall

The Arecibo Remote Command Center (ARCC) at the University of Texas at Brownsville is currently engaged in searching for radio pulsars in collaboration with a multi-beam galactic plane survey, P-ALFA, ongoing at the Arecibo radio observatory. ARCC is an integrated research/education facility that allows students at the high school and undergraduate level to be directly involved with the research at the Arecibo telescope. We discuss the progress of our search effort that currently uses the PRESTO pulsar search pipeline. Web based tools were developed so that students could rank the pulsar candidates created by the PRESTO analysis. We describe these tools and present the current pulsar candidates found.

337 *Supernovae* Poster Session *Exhibit Hall*

337.01

Evaluating Systematic Dependence of Type Ia Supernovae: The Influence of Progenitor Central Density Brendan K. Krueger¹, A. P. Jackson¹, A. C. Calder¹, D. M. Townsley², E. F. Brown³, F. X. Timmes⁴ ¹Stony Brook University, ²University of Alabama, ³Michigan State University, ⁴Arizona State University. Exhibit Hall

We present a study of type Ia supernovae in the single-degenerate scenario, in which a white dwarf accretes mass from a companion star until it approaches the Chandrasekhar limiting mass and an explosion ensues. We investigate progenitor models with a range of central densities to study the influence of this parameter on explosion outcome. We present a suite of simulations from a well-controlled statistical study that allows us to quantify the effects of a variety of initial conditions. We present details of the models, including the mass and distribution of ⁵⁶Ni, the radioactive decay of which powers the light curve. Our results indicate that progenitors with a higher central density produce less ⁵⁶Ni and hence a dimmer event. We combine our results with those from previous studies by our collaboration to explore trends in explosion brightness that follow from properties related to the morphology and color of the host galaxy.

This work was supported by NASA under grant No. NNX09AD19G and utilized resources at the New York Center for Computational Sciences at Stony Brook University/Brookhaven National Laboratory, which is supported by the U.S. Department of Energy under Contract No. DE-AC02-98CH10886 and by the State of New York.

337.02

One Or Two Populations Of Type Ia Supernovae?

Will Eagan¹, B. Connolly², N. Connolly¹ ¹*Hamilton College*, ²*University of Pennsylvania*.

Exhibit Hall

Recent analyses of the rise-times of Type Ia supernovae (SNe Ia) have suggested that there may exist two distinct populations of SNe Ia. In order to help resolve the controversy, we use the Schwarz Information Criterion (SIC) to quantify the belief that SN Ia rise-times are best described by a single-population model versus a two-population model.

337.03

Comparative Analysis of Peculiar Type Ia 1991bg-like Supernovae Spectra Brandon Doull¹, E. Baron¹

¹The University of Oklahoma.

Exhibit Hall

Spectroscopic analyses of Type Ia supernovae have shown there exist four spectroscopic groups known as core normal, cool, broad-line, and shallow silicon. 1991bg-likes are cools, and cools are dim, undergo a rapid decline in luminosity, and produce significantly less 56 Ni than normal Type Ia supernovae. 1991bg-likes also have an unusually deep and wide trough in their spectrum around 4200 Å and a relatively strong Si II absorption at 6150 Å. We examine the spectroscopy of supernova 1991bg and 1991bg-likes using the highly parameterized synthetic spectrum code SYNOW and find a general agreement with similar studies. Our analysis reveals that this group of supernovae is fairly homogeneous, with many of the blue spectral features fitted by Fe II. The nature of the spectroscopic

commonalities as well as the variations in the class is discussed. Further, we attempt to define borders of the class by examining intermediates such as 2004eo.

337.04

Optimization of Optical Cross-Correlation Filters for Type Ia Supernova Classification and Redshift Estimation

Andrew Cisler¹, D. Gerdes¹

¹University of Michigan.

Exhibit Hall

Upcoming wide-field optical surveys, such as the Dark Energy Survey, are expected to detect thousands of Type Ia supernovae. Classification of these supernovae and estimation of their redshift has traditionally required time-consuming spectroscopic followup. Optical cross-correlation filters (Scolnic et al., 2009) have the potential to be an efficient, low-cost alternative. This method employs a pair of comb filters optimized for sensitivity to features in the SNe Ia spectrum that are not present in supernovae of other types. We have used a Markov Chain Monte Carlo to optimize the parameters of the two cross-correlation filters, using observed supernova spectra for validation. We present results for the redshift estimation accuracy and classification efficiency.

337.05

Impact Of Type Ia Supernova Ejecta On The Binary Companion

Kuo-Chuan Pan¹, P. M. Ricker¹, R. E. Taam²

¹Department of Astronomy, University of Illinois at Urbana-Champaign, ²Department of Physics and Astronomy, Northwestern University.

Exhibit Hall

Type Ia supernovae are thought to be due to thermonuclear explosions of carbon-oxygen white dwarfs in close binary systems. In the single-degenerate scenario, the companion star is non-degenerate and can be significantly altered by the explosion. We explore this interaction by means of three-dimensional adaptive mesh refinement (AMR) simulations using the FLASH code. We consider several different companion types, including red giants, main-sequence-like stars, and helium stars, and we include the symmetry-breaking effects of orbital motion, Roche-lobe overflow, and pre-supernova mass loss. Our analysis focuses on mass loss by the companion, contamination of the companion's atmosphere by supernova ejecta, and post-supernova motion of the companion relative to the ejecta. We discuss the implications of our results for variation in Type Ia supernova properties and searches for remnant companion stars.

337.06

Nucleosynthesis from Off-Center Collisions of Two White Dwarfs

Themis Athanassiadou¹, W. Hawley¹, F. X. Timmes¹

¹Arizona State University.

Exhibit Hall

We present 3D simulations of off-center collisions between two white dwarfs to explore the possibility of such events being part of the overall Type Ia Supernovae (SNIa) population. In particular, we investigate collisions of carbon-oxygen white dwarfs of masses spanning the 0.6 - 0.9 solar masses over a range of non-zero impact parameters using the Eulerian adaptive-grid code FLASH. Preliminary results indicate 0.0 - 0.5 solar masses of 56Ni and 0.1 - 0.3 solar masses of unburned carbon and oxygen, making such collisions a candidate for producing sub-luminous supernovae, such as SN 1991bg, SN 1992K, and SN 2005bl. We also compare our results with similar simulations carried out using a Lagrangian particle SPH code, and comment on the conservation of angular momentum in a grid-based code.

Testing the Schwartz Information Criteria with Simulated Supernova Light Curves Anne Vilsoet¹, B. Connolly², N. Connolly¹

¹Hamilton College, ²University of Pennsylvania. Exhibit Hall

Type Ia supernovae (SNe Ia) are a staple of experimental cosmology due to their uniquely uniform intrinsic brightnesses, allowing them to be used as standard candles. Recently, however, there have been some questions raised about whether or not there are one or two populations of SNe Ia. We have performed extensive Monte Carlo simulations to test the ability of the so-called Schwartz Information Criterion (SIC) to accurately predict whether available supernova data comes from a single population or from two.

337.08

Turbulent Flame Speed and the Deflagration-to-Detonation Transition

Alexei Y. Poludnenko¹, E. S. Oran¹

¹Naval Research Lab.

Exhibit Hall

Turbulent thermonuclear burning fronts are presently believed to be the key component of the explosion mechanism powering type la supernovae (SNIa). Rapid increase in intensity of turbulent motions inside the white dwarf in the course of the explosion causes wrinkling of the flame, which significantly increases its surface area and, thus, accelerates the flame. This creates tightly packed flame configurations with high local flame curvature. Furthermore, small-scale turbulence begins to penetrate the flame, thus modifying its structure and altering its properties. Even in the thin reaction zone regime, i.e., when turbulence has disrupted only the preheat zone of the flame, the turbulent flame may be significantly different locally from a planar laminar burning front. Large-scale numerical modeling of SNIa requires the use of subgrid-scale models which accurately reproduce local properties, and in particular the local speed, of the turbulent flame formed in the presence of intense turbulence. We present results of the direct numerical simulations aimed at studying the mechanisms which control the turbulent flame speed in the thin reaction zone regime. Simulations were performed using the massively parallel reactive-flow code Athena-RFX. The increase of the flame surface area is the primary process responsible for accelerating the flame. We find, however, a significant additional increase in flame speed at high turbulent intensities. Such accelerated burning is the result of flame collisions in a tightly packed turbulent flame. Failure to account for this process in subgrid models can lead to the underestimation of the turbulent flame speed by as much as 30-50%. Finally, we discuss the implications of these results for the process of the deflagration-to-detonation transition.

This work was supported in part by the Naval Research Laboratory, the Office of Naval Research, the Air Force Office of Scientific Research, and by the National Science Foundation through the TeraGrid resources.

337.10

Hubble Space Telescope And Ground-based Observations Of SN 2005hk And SN 2008a: SN 2002cx-like Type Ia Supernovae

Curtis McCully¹, S. W. Jha¹, R. J. Foley², P. M. Garnavich³

¹*Rutgers, The State University of New Jersey,* ²*Harvard-Smithsonian Center for Astrophysics,* ³*University of Notre Dame.*

Exhibit Hall

Type Ia supernovae (SNe Ia) have been very successful tools for studying the history of cosmic expansion and led to the discovery of the accelerating universe and dark energy. However, the explosion

mechanism and progenitors for SNe Ia are still not fundamentally well understood. We present results from late time (up to 600 days past maximum brightness) HST and ground based observations of two typical members of the SN 2002cx-like subclass of peculiar SNe Ia: SN 2005hk and SN 2008A. At late times, these objects are characterized by significant amounts of high density, low velocity material giving a unique opportunity to resolve spectral features that are blended in normal SNe Ia. We identify permitted Fe I and Fe II lines, allowing us to calculate a characteristic temperature, and use the ratio between permitted and forbidden Ca II lines to constrain the density. We find that the density stays extraordinarily high out to late phases, implying enhanced cooling. However, we do not confirm the presence of the "infrared catastrophe" that is generically predicted by SN models as the ejecta cools. We also constrain explosion models for these objects: the lack of [0 I] 6300 A emission allows us to rule out the possibility that these peculiar objects are pure deflagration explosions that leave large amounts of unburned material in the innermost layers of the ejecta. Understanding what makes these SNe so different from their normal cousins has the promise to clarify these key systematic uncertainties in their use for cosmology.

337.11

Spectroscopic Diversity of Type Ia Supernova at Maximum Light

Eric Hsiao¹, A. Conley², D. A. Howell³, M. Sullivan⁴, C. J. Pritchet⁵, F. D. A. Hartwick⁵, M. M. Phillips⁶, P. E. Nugent¹, N. Suzuki¹

¹LBNL, ²University of Colorado, ³Las Cumbres Observatory Global Telescope Network, ⁴University of Oxford, United Kingdom, ⁵University of Victoria, Canada, ⁶Las Campanas Observatory, Carnegie Observatories, Chile.

Exhibit Hall

While the spectral features and their phase evolution of the majority of Type Ia supernovae (SNe Ia) are remarkably uniform, the advent of large spectroscopic data sets reveal subtle, but real, diversity among SNe Ia. To understand the origin of the observed variations, we conduct a systematic study of the feature shapes using the technique of principal component analysis (PCA). With the aid of PCA, the multidimensional spectral information is reduced to a few components, quantifying the subtle variations in the feature shape. Using the projections of the data on these principal components, it is shown here that light-curve shape is the main driver of the spectroscopic diversity at maximum light for every spectral feature in the rest-frame optical. The correlation points to composition of the ejecta and temperature which governs the speed of the ionization evolution as the main driver of the variation, while the effects of asymmetry appear to be sub-dominant at this phase. We also employ the same technique to study any differences in the spectroscopic properties between high-redshift and nearby SNe Ia, and also between SNe Ia of a range of host mass.

337.12

The Intrinsic Color of Type Ia Supernovae Depends on Ejecta Velocity

Ryan J. Foley¹

¹Harvard Smithsonian CfA.

Exhibit Hall

The intrinsic maximum-light B-V color of a Type Ia supernova (SN Ia) depends on the velocity of its ejecta at maximum brightness. Separating SNe Ia in two classes based on their ejecta velocity (normal and high-velocity), we notice that (1) for low and moderate reddening, the samples have similar extinction laws, (2) the bluest members of the high-velocity sample are significantly redder (by ~0.1 mag) than the bluest members of the normal sample, and (3) the cumulative distribution functions (CDFs) of the two samples have extremely similar shapes, but the high-velocity CDF is offset by ~0.1 mag to the red. We conclude that these samples have intrinsically different maximum-light colors. This effect can be

explained by additional line blanketing in the B band for the high-velocity objects. We discuss the implications of this result, including how using this information will improve distance estimates to SNe Ia.

337.13

Twin Supernova Studies with SNe Ia from SNfactory

Hannah Fakhouri¹, G. Aldering¹, C. Aragon¹, E. Hsiao¹, S. Loken¹, P. Nugent¹, S. Perlmutter¹, K. Runge¹, R. C. Thomas¹, P. Antilogous², S. Bongard², A. Canto², R. Pain², C. Wu², N. Chotard³, Y. Copin³, E. Gangler³, R. Pereira³, G. Smadja³, E. Pecontal⁴, C. Baltay⁵, D. Rabinowitz⁵, R. Scalzo⁵, C. Buton⁶, M. Kerschhaggl⁶, M. Kowalski⁶, K. Paech⁶, C. Tao⁷

¹Lawrence Berkeley National Lab, ²Laboratoire de Physique Nucleaire et des Hautes Energies, Universite Pierre et Marie Curie Paris 6, Universite Paris Dederot Paris 7, France, ³Institut de Physique Nucleaire de Lyon, France, ⁴Centre de Recherche Astronomique de Lyon, France, ⁵Yale University, ⁶Physikalisches Institut Universitat Bonn, Germany, ⁷CPPM, France.

Exhibit Hall

We present a study of twin supernovae with spectrophotometric timeseries of nearby Type Ia supernova from the Nearby Supernova Factory (Aldering, et al. 2002). One advantage of "twins" is they offer the best opportunity for having objects with the same intrinsic luminosities and colors, ostensibly leaving only extrinsic factors such as dust to explain any observed differences in brightness and color. Using well-sampled timeseries data for over 100 nearby Hubble-flow SNe Ia, we study the impact of dust on the brightness differences of SN Ia twins in order to improve the standardization of these standardizable candles that have been and will continue to be a primary tool in the determination of cosmological parameters. Specifically we are able to solve for the relative extinction and R_v needed to bring the twins into near-perfect agreement. We will present a study of the resulting distribution of R_v. In searching for twin supernovae we have found groups of SNe, again differing only by a dust law that accounts for the brightness differences. These groups allow us to look for similarities in subsets of SNe and explore spectrophotometric differences from group to group.

337.14

Tests of Environmental Effects on Type Ia Supernova Production

Suzanna M. Sadler¹, L. Strolger¹, S. Wolff¹

¹Western Kentucky University.

Exhibit Hall

The host galaxy environments of type Ia supernovae (SNe Ia) provide our best opportunity for constraining the mechanism(s) of the SN Ia progenitor system, i.e., the stars involved, the incubation times, and the sensitivity of SNe Ia to changes in the local gas-phase metallicity. The latter can affect the luminosity of the resultant event, and possibly the success in ultimately yielding a SN Ia. We seek to solidify possible environmental trends in SN Ia rates from direct measures of host galaxy properties, using the sample collected by the Nearby Galaxies Supernova Search project. This study will uncover which has the greatest influence on SN Ia production efficiency: parent population age, rate of star-formation, or metallicity.

Here, we will show some preliminary results from SSP model fitting (of age and [Fe/H]) to a selection of hosts obtained thus far from this study. The complete sample will provide a validity test of the mostly indirect trends being established for SNe Ia from the LOSS, SDSS, SNfactory and other surveys, and may ultimately steer future investigations towards more precise SN Ia cosmology.

Radio Observations Reveal the Mass Loss History of Type Ibc Supernova Progenitors Sarah Wellons¹, A. M. Soderberg²

¹Princeton University, ²Harvard-Smithsonian Center for Astrophysics. Exhibit Hall

We present extensive radio observations of the nearby Type Ibc supernovae 2004cc, 2004gq, and 2004dk spanning ∆ t≈ 8-1800 days after explosion. Using a dynamical model developed for synchrotron emission from a slightly decelerated blastwave, we estimate the velocity and energy of the fastest ejecta and the density profile of the circumstellar medium. The blastwaves for all three supernovae are characterized by non-relativistic velocities of $v \approx (0.1-25)c$ and associated energies of $E \approx (2-10) \times 10^{47}$ erg, in line with the expectations for a typical homologous explosion. Smooth, stellar wind density profiles are indicated by the early radio data and we estimate the progenitor mass loss rates to be $\circ M \approx (8-40) \times$ 10^{-6} M_{\odot} yr⁻¹ (wind velocity, v_w=103 km s⁻¹). These properties are consistent with those of Wolf-Rayet stars, the favored progenitors of SNe Ibc including those associated with long-duration gamma-ray bursts. However, at late time, each of these SNe show evidence for abrupt radio variability which we attribute to significant circumstellar density modulations (factor of ~ 5-100) at radii of R≈ (1-50)× 10¹⁶ cm. For SN 2004gq, the density modulations are marginally consistent with the expectations for a variable and/or clumpy Wolf-Rayet line-driven wind. However, in the case of SNe 2004cc and 2004dk, the density modulations are more intense, $\circ M > \sim 10^{-4} M_{\odot} \text{ yr}^{-1}$, and possibly attributed to continuumdriven winds or hydrodynamic eruptions. We compare the circumstellar environments for these three SNe with those of other Type Ibc supernovae and nearby gamma-ray bursts and find that they are characterized by a more violent progenitor mass loss history in the decades leading up to explosion. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 0754568 and by the Smithsonian Institution.

337.16

A Study of the Relation Between the Properties of Type Ib and Ic Supernovae and their Host Galaxies Daneil Handlin¹

¹Harvard College.

Exhibit Hall

This work explored the relationship of SNe Ibc to their host galaxies. Using a set of well-characterized SNe lbc lightcurves, the properties of these SNe lightcurves (peak magnitude and decay time) were retrieved and catalogued. The properties of the supernova host galaxies (star formation rate, physical size, and metallicity) were then derived by obtaining SED data on each galaxy from the NASA NED database and using well-established empirical relations that correlate the flux from the galaxies in certain bands to the galaxy's s star formation rates and metallicities. SNe lbc have not been well characterized in a systematic way; this study is the first to make use of a large sample of calibrated lightcurves for these supernovae. In addition, several well-studied supernovae from the literature were included in the study. Each supernova property was compared to the derived galaxy properties by plotting each pair (e.g., peak SN magnitude vs. host galaxy star formation rate) and then conducting a correlation test to determine the existence and strength of the correlation between the supernovae and galaxy properties in each case. This test was conducted for each supernova type. The goal of the research is to determine what systematic differences may exist between the environments of SNe Ib and Ic, in order to shed light on possible differences in the explosion mechanisms of these SN types. The supernova lightcurve contains data on the explosion itself while the host galaxy properties yield information on the progenitor star; the hope is that these two datasets can be linked. Ultimately the goal is to better understand the relationship between SNe and GRBs. The property sets did not yield

obvious correlations, with the exception of a correlation between host galaxy star formation rate and lightcurve width for SNe Ib.

337.17

SYNOW Line Analysis of Type Ib/IIb Supernovae

Mary C. Hogan¹, D. Branch¹, E. Baron¹

¹University of Oklahoma.

Exhibit Hall

A line identification study of Type Ib/IIb supernovae is carried out by modeling their spectra with SYNOW. Model spectra were fit to various supernovae including the Type IIb SN 1993J and SN 2008ax. No detailed early-time line identification study for these well observed supernovae had been completed previously. Hydrogen Balmer lines in these supernovae classified as the transitory Type IIb class are seen in the fits. Focus was maintained on matching the H β feature since SYNOW has difficulty fitting the emission strength for the H α feature due to its non-resonant scattering source function. Other interesting line identifications include the apparent presence of Al II in SN 2008ax and the apparent lack of Ba II which had been previously suggested in SN 1993J. Apart from the inability to handle the source function for H α , good fits were obtained for the spectra with lines of plausible ions.

337.18

An HST Search for the Progenitor of the Type Ib Supernova 20100 in NGC 3690/Arp 299

Howard E. Bond¹, A. Aloisi¹, C. Garmany², B. James¹, J. Newton³, T. Puckett⁴, S. T. Sohn¹, R. P. van der Marel¹, G. Nelemans⁵, R. Voss⁵, M. Nielsen⁵

¹STScI, ²NOAO, ³Puckett Observatory, Canada, ⁴Puckett Observatory, ⁵Radboud Universiteit Nijmegen, Netherlands.

Exhibit Hall

Several progenitor stars of Type II supernovae (SNe) have been identified in archival pre-explosion HST images. All of them are consistent with being red supergiants, as had been expected but never actually confirmed until the advent of HST imaging.

The hydrogen-deficient Type Ib and Ic SNe are in a less satisfactory state. They are believed to be corecollapse SNe arising from massive stars that have lost their H envelopes. Unfortunately, however, there has never been an identified progenitor of an SN Ib or Ic, so it remains uncertain whether they are massive Wolf-Rayet stars, or less-massive stars in interacting binaries.

The Type Ib SN 2010O was discovered by the amateur members of our team. It appeared in the starburst interacting galaxy NGC 3690 (Arp 299). It offers a tantalizing new opportunity, because NGC 3690 has been the subject of very extensive HST observations, ranging from the UV and optical to the near-IR, obtained before the outburst. SN 2010O is also interesting because of its close proximity to a variable X-ray source discovered by our team in pre-explosion Chandra images, which may support the interacting-binary scenario.

We imaged SN 2010O with the HST's Wide Field Planetary Camera 3 in June 2010. We find that it lies close to, but not within, a young compact cluster. There is no conspicuous optical progenitor star in the pre-outburst HST images.

We will discuss the implications for the progenitor objects of Type Ib supernovae. Funding from STScI is gratefully acknowledged.

337.19 Late-Time Optical Spectra of Core-Collapse Supernovae Dan Milisavljevic¹, R. Fesen¹

¹Dartmouth College.

Exhibit Hall

Optical spectra of several core-collapse supernovae obtained many years to decades after outburst are presented and discussed with the aim of understanding general properties of late-time emission. Common to most of these spectra are strongly asymmetric line profiles exhibiting predominantly blueshifted emission in hydrogen and/or oxygen, with major emission peaks centered at -2000 to -6000 km/s. Observed emission line profiles and relative line fluxes are compared against theoretical models to probe the chemical abundances of the ejecta and the extent of turbulent mixing. We discuss the possible nature of the observed blueshifted peaks and likely late-time emission energy sources including circumstellar interaction, radioactive decay, and pulsar wind nebulae.

337.20

On the Spatial Distributions of Type IIn Supernovae

Teresa Ashcraft¹, C. Raskin¹, E. Scannapieco¹, J. D. Neill²

¹Arizona State University, ²California Institute of Technology.

Exhibit Hall

One of the most unique and mysterious classes of supernovae are Type IIn. Type IIn supernovae spectra are characterized by strong, relatively narrow emission lines, most notably $H\alpha$, which are associated with a circumstellar medium (CSM) surrounding the progenitor star that become excited once the supernova ejecta collide with it. The exact nature of IIn progenitors is still debatable with many believing association with massive stars.

The intra-host spatial distributions of transients provide vital information for constraining progenitor properties. We compare the spatial distributions of type IIn supernovae in near ultra-violet images from the GALEX space telescope and g' images from the Sloan Digital Sky Survey of supernova hosts from the Padova-Asiago catalog. We find that the spatial distribution of type IIn supernovae are correlated with the distribution of light in their hosts in g', but are anti-correlated in the near ultra-violet. This implies either lower progenitor masses then previously thought, or a unique evolutionary pathway.

337.21

The Expanding Photosphere Method (EPM): Distance Calculations to Type II-P Supernovae and a Comparison with the Standard Candle Method

J. Emilio Enriquez¹, D. C. Leonard², D. Poznanski³, A. V. Filippenko⁴, R. Chornock⁵, R. J. Foley⁵, M. Ganeshalingam⁴, W. Li⁴, J. M. Silverman⁴

¹SDSU / SETI Institute, ²SDSU, ³LBL / UC Berkeley, ⁴UC Berkeley, ⁵UC Berkeley / CfA. Exhibit Hall

The use of independent methods to calculate extragalactic distances is important to help constrain cosmological parameters and to provide mutual checks on the external accuracy of other distance measuring techniques. In this work we present EPM distance estimates to a group of nearby (≤150 Mpc) Type II-Plateau Supernovae (SN-IIP) that are drawn from a sample for which distances have previously been determined by Poznanski et al. (2009) using the Standardized Candle Method (SCM), an independent distance-measuring technique for SNe II-P. We use the same photometric and spectral data as was used by Poznanski et al. (2009), which enables a direct comparison between the two techniques. To calculate our EPM distances we use the dilution factors of Jones et al. (2009), which were derived from the atmosphere models of Dessart & Hillier (2005b), and employ the filter subsets {BV}, {BVI}, and {VI}. Our "best" EPM distance estimates are derived as the mean of the three individual

distances. We compare the EPM and SCM distance measurements and speculate on potential causes of any discrepancies found between our study and a parallel one carried out by Olivares et al. (2010) using a different dataset (which found a ~40% difference between EPM and SCM distances, in the sense that EPM distances were systematically larger). Finally, we use our sample of EPM distances to SNe II-P to estimate the Hubble constant. We are grateful for the financial support of NSF grant AST-0908886, the TABASGO Foundation, and (for DP) an Einstein Fellowship.

337.22

Optical And Infrared Analysis Of Type II SN 2006bc

Joseph S. Gallagher¹, G. Clayton², J. Andrews², B. Sugerman³, J. Clem², M. Barlow⁴, B. Ercolano⁵, J. Fabbri⁴, R. Wesson⁴, M. Otsuka⁶, M. Meixner⁶

¹University of Cincinnati - Raymond Walters College, ²Louisiana State University, ³Goucher College, ⁴University College London, United Kingdom, ⁵University of Exeter, United Kingdom, ⁶Space Telescope Science Institute.

Exhibit Hall

We present nebular phase optical imaging and spectroscopy and near-IR and mid-IR imaging of the Type II SN 2006bc. Observations reveal the central wavelength of the symmetric H-alpha line profile to be blue-shifted with respect to the galactic H-alpha emission by day 325. This is likely due to an asymmetric explosion in the iron-peak elements resulting in a larger mass of 56NI and higher excitation of hydrogen on the near side of the SN explosion. We also observe a gradual blue-shifting of this H-alpha peak that could be indicative of dust formation in the ejecta. Radiative transfer modeling in currently underway to quantify the amount and composition of dust formed during this SN event. Although showing a normal peak brightness, V \sim -17.2, for a core-collapse SN, 2006bc fades by \sim 6 mag during the first 400 days suggesting either a relatively low 56Ni yield, an increase in extinction due to new dust, or both. A short duration flattening of the light curve is observed from day 416 to day 541 suggesting an optical light echo. Based on the narrow time window of this echo, we discuss implications on the location and geometry of the reflecting CSM.

337.23

Magnetic Field Evolution in Three-dimensional Simulations of the Stationary Accretion Shock Instability

Eirik Endeve¹, C. Cardall¹, R. Budiardja², S. Beck², A. Bejnood², A. Mezzacappa¹

¹ORNL, ²University of Tennessee.

Exhibit Hall

The stationary accretion shock instability (SASI) plays an important role in modern simulations of corecollapse supernovae. With the intent to study magnetic field generation and the possible impact of magnetic fields during the crucial nonlinear phase leading to the explosion of massive stars, we have carried out high-resolution, three-dimensional magnetohydrodynamic simulations of the SASI. Turbulent flows emerging from the operation of the spiral SASI mode result in exponential growth of the magnetic energy. From initial conditions in the range expected for slowly rotating progenitor stars, we find that saturation of the magnetic energy can occur within a typical explosion time scale. Implications for neutrino-powered supernovae and neutron star magnetization are considered.

Identifying the Origin and Heating Mechanism of Warm Dust in the Supernova Environment Roger Chevalier¹, O. D. Fox², M. Skrutskie¹

¹Univ. of Virginia, ²NASA/GSFC/ORAU.

Exhibit Hall

Recent observations suggest that Type IIn supernovae exhibit late-time infrared emission from warm dust more than typical core-collapse events. Mid-infrared wavelengths span the peak of the thermal spectral energy distribution from dust with temperatures ranging 100 - 1000 K, providing strong constraints on the dust mass, temperature, and, thereby, the luminosity. Here, we show how to adopt these quantities as useful diagnostics for disentangling the various origins and heating mechanisms of warm dust in the supernova environment, which, once determined, offer useful clues regarding the circumstellar medium, supernovae progenitor, and explosion dynamics. The techniques are applied to a sample of 68 Type IIn supernovae surveyed by Spitzer. The sample represents all known Type IIn supernovae within 250 Mpc from the past 10 years that remained unobserved by Spitzer more than 100 days post-discovery. The detection of late-time emission from nine targets (>10%) nearly doubles the database of existing mid-infrared observations of Type IIn supernovae. In most cases, a circumstellar shock echo from pre-existing dust likely dominates the observed late-time infrared flux. The powering luminosity likely originates from optical emission generated by continuous shock interaction with the surrounding dense circumstellar medium, as opposed to the peak supernova luminosity. The associated mass loss rates are consistent with Luminous Blue Variable (LBV) progenitors.

337.25

The Ultra-Violet Properties of Type II/P/L/n Supernovae

Tyler A. Pritchard¹, P. W. A. Roming²

¹*Pennsylvania State University,* ²*Southwest Research Institute.*

Exhibit Hall

We present a sample of ultra-violet (UV) observations of nearby Type II, IIP, IIL, and IIn Supernovae (SNe) observed with the Swift Ultra Violet/Optical Telescope (UVOT). We examine the UV light curves, decay rates, and color evolution of the SNe and subtypes. We proceed to look at the effects of extinction and the UVOT uvw1/uvw2 filter red-tail on the various parameters through the use of Swift observed UV-spectra for the sample cases of the Type IIP SNe 2005cs and 2006bp.

337.26

The Peculiar Type II Supernova 2000cb

Io Kleiser¹, D. Poznanski¹, D. Kasen², A. V. Filippenko¹, R. Chornock³, M. Ganeshalingam¹, R. P. Kirshner³, W. Li¹, T. Matheson⁴, P. E. Nugent⁵, J. M. Silverman¹

¹Department of Astronomy, University of California, Berkeley, ²Department of Physics, University of California, Berkeley, ³Harvard-Smithsonian Center for Astrophysics, ⁴National Optical Astronomy Observatory, ⁵Lawrence Berkeley National Laboratory.

Exhibit Hall

Unusual supernovae (SNe) shed light on the more mundane objects by allowing us to explore the edges of the physical conditions that can lead a star to its violent demise. SN 1987A revealed that blue supergiants can explode as Type II SNe, along with the red supergiants that produce the bulk of that population. This revolutionized our perspective on the possible outcomes of massive stellar evolution. We present here optical photometry and spectroscopy gathered on SN 2000cb, which is neither a standard Type II SN nor a SN 1987A analog. The light curve of SN 2000cb is reminiscent of that of SN 1987A in shape, with a slow rise to a late optical peak, but the timescales and color evolution of these two objects are quantifiably different. Spectroscopically, SN 2000cb seems like a normal Type II but with photospheric velocities that far exceed those measured for SN 1987A or normal SNe II, above 18,000 km/s for the H-alpha absorption line at early times. The red colors, high velocities, and late peak all point toward a scenario involving the high-energy explosion of a small-radius star that has shed a significant fraction of its hydrogen envelope. We derive a rate for this loosely defined class of blue supergiant explosions on the order of 2% of the core-collapse SN rate.

We are grateful for the support of NSF grant AST-0908886, AST-0907903, and the TABASGO Foundation.

337.27

Linking Type IIN Supernovae With Massive Progenitors

Leah N. Huk¹, C. Peters¹, J. Hoffman¹

¹University of Denver.

Exhibit Hall

Within the two major supernovae types, several subcategories have arisen in recent years that mainly differ from each other in their spectral characteristics. However, it is unclear which types of massive stars give rise to each particular subcategory of supernovae. Studying the circumstellar material (CSM) surrounding IIn supernovae, the result of mass loss episodes prior to core collapse, allows us to constrain the properties of the progenitor stars. We use a three-dimensional Monte Carlo radiative transfer code called SLIP to model hydrogen-alpha emission line profiles of IIn supernovae. The code allows us to vary several parameters of the CSM including geometry, temperature, optical depth, and initial photon distribution. We present initial comparisons of our model results with observations of SN 1997eg from the Keck Telescope using chi-squared analysis to identify the best fit from a grid of 108 models. Future comparisons of additional IIn supernovae with our models will provide overall insight into common trends amongst CSM characteristics and thus properties of IIn progenitors. This research is supported by the National Science Foundation, the University of Denver, and Vanderbilt University.

337.28

Core-Collapse Supernovae in the LSST Era

Amy Y. Lien¹, B. D. Fields¹, J. F. Beacom², N. Chakraborty¹, A. Kemball¹ ¹University of Illinois at Urbana-Champaign, ²Ohio State University. Exhibit Hall

A main science goal of LSST is to detect Type Ia supernovae, but the survey will also revolutionize our understanding of core-collapse events. LSST will observe ~ 10^5 core-collapse supernovae per year out to $z \sim 1$ and obtain the cosmic supernova rate by direct counting, in an unbiased way and with high statistics. Many science applications will therefore be feasible. Here, we discuss synergies with neutrino detectors and radio observations. The cumulative (anti)neutrino production from all core-collapse supernovae within our cosmic horizon gives rise to a diffuse supernova neutrino background (DSNB) which is on the verge of detectability. The observed flux depends on supernova physics, but also on the cosmic history of supernova explosions. The high precision measurement of the cosmic supernova rate will allow precise predictions of DSNB and make it a strong probe of optically invisible supernovae, which may be unseen either due to unexpected large dust obscuration in host galaxies, or because some core-collapse events proceed directly to black hole formation and fail to give an optical outburst. Another way to uncover optically invisible supernovae would be the next generation radio telescope, the Square Kilometer Array (SKA). SKA will be capable of unbiased synoptic searches over large fields of view with remarkable sensitivity and explode the radio core-collapse supernova inventory from the current number of several dozen in the local universe to ~ 600 yr⁻¹ deg⁻² out to z ~ 5. SKA will be complementary to LSST and together provide crucial information for dust evolution and star-formation at high redshift.

The First Year of the Palomar Transient Factory Type Ia Supernova Program

Peter E. Nugent¹, D. A. Howell², M. Sullivan³

¹Lawrence Berkeley Lab., ²LCOGT/UCSB, ³University of Oxford, United Kingdom. Exhibit Hall

The Palomar Transient Factory (PTF) is an astronomical wide-field survey designed to search for optical transient and variable sources. PTF began on-sky operations in early 2009. It is fully-automated, including a wide-field survey camera, an automated real-time data reduction pipeline and transient classifier, a dedicated photometric follow up telescope, and a full archive of all detected sources. One of the PTF Key Projects is focused on Type Ia Supernovae (SNe Ia). The core science goals of this program are the creation of a new SN Ia optical and near-IR Hubble diagram with z &It; 0.1, a measurement of both volumetric and host-galaxy dependent SN Ia rates, and a determination of the dependence of SN Ia properties on their host properties and local environments. The result of these efforts should lead to improvements in both our understanding of the physics of these events and their utility as cosmological probes. During the first year of operation, PTF has discovered and spectroscopically classified over 500 SNe Ia. Here we present some early results from this survey, including UV studies of SNe Ia carried out on the Hubble Space Telescope, the host properties of the PTF SNe Ia, and an analysis of some of the youngest SN Ia spectra taken to date.

337.30

A Complete Sample of Supernova Host Galaxies Robert \mbox{Quimby}^1

¹Caltech.

Exhibit Hall

Traditionally, supernova surveys have drawn their samples by monitoring pre-selected lists of host galaxies. More recently, some surveys have made efforts to ignore host properties when selecting candidates, but because of limited resources they must usually add additional selection criteria, such as the color or light curve shape of the transient, in order to select the best targets for a specific study. Since 2004, we have conducted a search for supernovae that is designed to select targets irrespective of their host environment, and we have spectroscopic classifications for all of the new transients detected. Here we report on the host galaxies of first 72 supernovae detected by ROTSE-IIIb as part of the Texas Supernova Search and the ROTSE Supernova Verification Project. The supernova sample includes everything from perfectly normal Type Ia and Type II, to spectroscopically peculiar events, to several of the host galaxy sample to the larger galaxy population. We cannot securely identify host galaxies brighter than -10 mag absolute for four of our discoveries, which suggests that these may be hostless, "tramp supernovae."

337.31

Supernova Science at LCOGT Dale Andrew Howell¹

¹Las Cumbres Observatory / UC Santa Barbara. Exhibit Hall

Las Cumbres Observatory Global Telescope (LCOGT) is building a global network of robotic telescopes to study supernovae and extrasolar planets. We are involved in the Palomar Transient Factory (PTF), Pan-STARRS1 (PS1), the La Silla Quest SN search, and the Supernova Legacy Survey (SNLS). Here we give an overview of supernova science at UCSB/LCOGT, including the latest results from these surveys.

3D Spectroscopic View of Supernovae Using Light Echoes

Armin Rest¹, R. J. Foley², B. Sinnott³, D. L. Welch³, C. Badenes⁴, A. V. Filippenko⁵, M. Bergman⁶, S. Blondin⁷, P. Challis², G. Damke⁸, H. Finley⁹, M. E. Huber¹⁰, D. Kasen⁵, R. P. Kirshner², T. Matheson¹¹, P. Mazzali¹², D. Minniti¹³, G. Narayan¹⁴, K. Olsen¹¹, D. Sauer¹⁵, R. C. Smith¹⁶, N. B. Suntzeff¹⁷ ¹Space Telescope Science Institute, ²Harvard-Smithsonian Center for Astrophysics, ³McMaster University, Canada, ⁴Benoziyo Center for Astrophysics, Israel, ⁵University of California, Berkeley, ⁶Gemini Observatory, Chile, ⁷Centre de Physique des Particules, France, ⁸University of Virginia, ⁹Drexel University, ¹⁰Johns Hopkins University, ¹¹National Optical Astronomy Observatory, ¹²Max-Planck-Institut fuer Astrophysik, Germany, ¹³Scuola Normale Superiore, Italy, ¹⁴Harvard University, ¹⁵Stockholm University, Sweden, ¹⁶Cerro Tololo Inter-American Observatory, Chile, ¹⁷Texas A&M University.

The study of light echoes from Galactic supernovae provides newly recognized observational benefits which we have only just begun to exploit. One benefit is the possibility of a three-dimensional spectroscopic view of a supernova. We have obtained several spectra of light echoes of the Cas A supernova. After properly accounting for the effects of nonzero dust filament extent and inclination, we find that even though the light-echo spectra are in general very similar, they show distinguishable differences in the line velocities on the order of ~4000 km/s that are in agreement with the structure seen in X-ray images. This is direct evidence that the Cas A supernova was an asymmetric explosion. We are grateful for the financial support of NSF grant AST-0908886 and AST-0907903

337.33

Imaging The Fe I Distribution In The SN 1885 (S And) Remnant

Robert A. Fesen¹, P. Hoeflich², A. J. S. Hamilton³

¹Dartmouth College, ²Florida State Univ., ³Univ. of Colorado.

Exhibit Hall

We present new Hubble Space Telescope images of the remnant of SN 1885 (S And) in M31 taken using the 2% ACS/WFC ramp filter FR388N to isolate the remnant's Fe I 3720 line absorption. The filter's ~100 Angstrom bandpass restricted the detection of Fe I line absorption to Fe-rich ejecta expanding with velocities +/-5000 km/s with respect to the plane of the sky. Comparisons with earlier ACS/WFC Ca I 4227 and Ca II 3934,3968 images taken in 2004 show a 0.1 arcsec displacement to the east of the Fe I absorption peak relative to the remnant's circular 0.8 arcsec diameter Ca II line absorption feature. While the off-center displacement of Fe I is in the same direction as seen in Ca I, the Fe I absorption feature is different in both size and structure and lies inside the outer Ca I absorption edge. We discuss various photoionization and SN Ia explosion model explanations for the observed Fe I off-center displacement from the remnant's geometric center.

This research was funded by NASA/HST GO program 11722.

337.34

Pulsar-driven Jets In Supernovae, LMXBs, SS 433, And The Universe John Middleditch¹

¹LANL.

Exhibit Hall

The model of pulsar emission through superluminally induced polarization currents (SLIP) predicts that pulsations produced by such currents, induced at many light cylinder radii by a rotating, magnetized body, as would be the case for a neutron star born within any star of more than 1.4 solar masses, will drive pulsations close to the axis of rotation. In SN 1987A, such highly collimated (<1 in 10,000) 2.14 ms pulsations, and the similarly collimated jets of particles which they drove, including 1e-6 solar

masses with velocities of up to 0.95 c, were responsible for the features of its very early light (days 3 - 20), its "Mystery Spot," observed slightly later (0.5 to 0.3 c, at days 30 - 50 and after), and still later, in less collimated form, its bipolarity. The kinematics of the jets in Sco X-1 are nearly identical, while those for SS 433 are lower (0.26 c), because of the absence of velocity "boosting" via collisions of heavy elements with lighter ones, due to the nearly pure hydrogen content of the supercritical accretion. SLIP also predicts that almost all pulsars with very sharp single pulses have been detected because the Earth is in a favored direction where their fluxes diminish only as 1/distance, and this has been verified in the laboratory as well as for the Parkes Multibeam Survey. The axially driven pulsations enforce a toroidal geometry onto all early SNRs, rendering even SNe Ia unsuitable as standard candles. SLIP also specifically predicts that gamma-ray-burst afterglows will be essentially 100% pulsed at 500 Hz in their proper frame. Finally, SLIP jets from SNe of the first stars may allow galaxies to form without the need for dark matter. This work was supported in part by the Department of Energy through the Los Alamos Directed Research Grant DR20080085.

337.35

Sn1978k: A Pearl Of An X-ray Source

Caroline Crews¹, E. M. Schlegel²

¹Univ of Texas at San Antonio and Texas Academy of Math & Sci, ²Univ of Texas at San Antonio. Exhibit Hall

We present the results of a 2008, the pearl anniversary, Suzaku observation of the X-ray-emitting SN1978K in NGC 1313. The X-ray spectrum is dominated by soft, ~0.6 keV, emission in broad agreement with previous observations over the past decade. We update and discuss the significance of the soft and hard band light curves.

337.36

Violent Encounters During The Great Eruption Of Eta Carinae And Other Luminous Transients Nathan Smith¹, D. Frew²

¹U. Arizona, ²Macquarie University, Australia.

Exhibit Hall

We present newly uncovered historical data containing over 50 observations of the brightness of Eta Carinae during the peak of its 19th century Great Eruption, which correct some mistakes in previously published lightcurves and paint a substantially different picture of the eruption. We compare the timing of brightening events to expected times of periastron encounters in the eccentric binary system, and we evaluate the extent to which such interactions may account for the observed variability. Periaston encounters may explain some aspects of the light curve, but new questions arise as well, and we discuss a possible physical model for the eruption. Finally, we mention potentially far-reaching implications for so-called "Supernova Impostors" and other luminous transients seen in other galaxies, which will be discovered in increasing numbers in upcoming transient searches like LSST.

338 *Evolved Stars, Cataclysmic Variables, Novae, Wolf-Rayet Phenomena* Poster Session *Exhibit Hall*

338.01

On the Ensemble Properties of Present-Day Cataclysmic Variables

Lorne A. Nelson¹, J. Goliasch¹

¹Bishop's Univ., Canada.

Exhibit Hall

We present the results of an extensive population synthesis study on the ensemble properties of the present-day Cataclysmic Variable (PDCV) distribution. Unlike previous studies, our analysis takes fully into account the nuclear evolution of the donor prior to the onset of mass transfer. One of the main conclusions is that He WD primaries are likely to contribute significantly to the PDCV population, and that their characteristic minimum orbital period (Pmin) values are different from those for systems with CO WD accretors. Additionally, the nuclear evolution of the donor also helps explain the number of systems found within the period gap. We also find a very sharp drop in the mass-transfer rate at Pmin. Assuming that the detectability of CVs scales with the mass-transfer rate, this can help explain the observational absence of "period bouncers". Although the synthetic results help explain many of the ensemble properties of PDCVs, significant discrepancies still exist (although many of these can be attributed to observational selection effects).

338.02

Optical Depth Effects in the X-ray Grating Spectra of Cataclysmic Variables

Eric M. Schlegel¹, H. V. Shipley²

¹Univ. of Texas, San Antonio, ²Texas A&M University.

Exhibit Hall

We examine the available spectra of cataclysmic variables that have been obtained using the Chandra HETG grating with a focus on describing optical depth effects in the emission lines. The data consist of β and α transitions of O~VIII, Ne~X, Mg~XI, Mg~XII, and Si~XIV. We compare the observed β/α ratios to theoretical predictions obtained using the APED to test whether the emission lies in the optically thin regime.

338.03

Phase-Resolved Cyclotron Spectroscopy and Polarimetry of HU Aquarii Mason T. Carney¹

¹University of Maine.

Exhibit Hall

In this work we investigate the polarization in B and V filters and spectra from 400nm-700nm of cyclotron radiation emitted from the polar HU Aquarii. By calculating the Stokes parameters of the light we can obtain information about the linear and circular polarization as well as position angle over the full orbit of the system. Our polarization light curves reveal that there is a pulse in circular polarization of $^{9\%} \pm 2.6\%$ in the B band and $^{5\%} \pm 2\%$ in the V band occurring from $\Phi = 0.6$ -0.7 that corresponds to a peak in magnitude in the photometric light curves. The Q component of linear polarization shows no evidence of nonzero values in either band when error bars are included. The linear U component shows $^{-7\%} \pm 3.5\%$ from $\Phi = 0.2$ -0.6 in the V band. This feature cannot be confirmed in the B band because the data is contaminated during that part of the orbital period due to cloudy observing conditions. Position angle appears to remain at ~130° in the V band throughout most of the orbit until $\Phi = 0.6$, at which

point its value slowly increases beyond 180° and drops to ~25°. We use a genetic algorithm modeling program to analyze spectra of HU Aqr from one year prior. Based on this technique, we conclude that HU Aqr has a magnetic field of B = 35.0-37.2, which is consistent with previous estimates by Schwope, et al. (2003). There is also evidence of divergence between the plasma temperature (kT) and the mass accretion rate over the full orbital period, which is indicative of inhomogeneities in the accretion column of HU Aqr.

338.04

The Anomalous Accretion Disk of the Cataclysmic Variable RW Sextantis

Albert P. Linnell¹, P. Godon², I. Hubeny³, E. M. Sion², P. Szkody¹ ¹Univ. of Washington, ²Villanova University, ³Univ. of Arizona. Exhibit Hall

The standard model for stable Cataclysmic Variable (CV) accretion disks (Frank, King and Raine 1992) derives an explicit analytic expression for the disk effective temperature as function of radial distance from the white dwarf (WD). That model specifies that the effective temperature, Teff(R), varies with R as ()^{0.25}, where () represents a combination of parameters including R, the mass transfer rate M(dot), and other parameters. It is well known that fits of standard model synthetic spectra to observed CV spectra find almost no instances of agreement. We have derived a generalized expression for the radial temperature gradient, which preserves the total disk luminosity as function of M(dot) but permits a different exponent from the theoretical value of 0.25, and have applied it to RW Sex (Linnell et al.,2010,ApJ, 719,271). We find an excellent fit to observed FUSE and IUE spectra for an exponent of 0.125, curiously close to 1/2 the theoretical value. Our annulus synthetic spectra, combined to represent the accretion disk, were produced with program TLUSTY, were non-LTE and included H, He, C, Mg, Al, Si, and Fe as explicit ions. We illustrate our results with a plot showing the failure to fit RW Sex for a range of M(dot) values, our model fit to the observations, and a chi² plot showing the selection of the exponent 0.125 as the best fit for the M(dot) range shown. (For the final model parameters see the paper cited.)

338.05

The Hot Components of AM CVn Helium Cataclysmics

Edward M. Sion¹, A. P. Linnell², P. Godon¹, I. Hubeny³ ¹*Villanova Univ.*, ²*Univ.Washington*, ³*Univ.Arizona*.

Exhibit Hall

The AM CVn helium-transfer cataclysmic variables are fundametally important because they are the progeny of double common envelope evolution, they are a principal source of low frequency gravitational wave emission, a laboratory for accretion and interior physics under extreme conditions and candidates for Type Ia supernovae. The hot component, consisting of a helium-rich white dwarf and disk, is the focus of our synthetic spectral analysis using the code BINSYN (Linnell& Hubeny 1996) which takes into account the donor companion star, the shock front which forms at the disk edge and the FUV and NUV energy distribution.

We report the first results from our multi-component study of helium accretion and white dwarf heating.

This research was supported by NASA ADP grant NN09AC94G and in part by NSF grant AST0807892, both to Villanova University.

338.06 Synthetic Spectral Ananlysis of the Nova-Like Variable KQ Mon Aaron Wolfe¹, E. Sion¹

¹Villanova University.

Exhibit Hall

KQ Mon is classified as a nova-like variable with an uncertain orbital period of 0.128 d. Optical spectra (Zwitter, T. & Munari, U.1994, A\&AS, 107, 503) reveal no emission lines but strong Balmer absorption features. High speed flickering has been observed indicative of accretion. IUE spectra reveal deep absorption lines due to C III, C II, Si III, Si IV, C IV, He II but no P Cygni profiles indicative of outflow. Its classification in Ritter and Kolb (2006) as a UX UMa type nova-like is uncertain. We have carried out the first synthetic spectral analysis of the IUE archival spectra of KQ Mon with realistic accretion disk models with vertical structure and high gravity photosphere models. The results of our model atmosphere and model accretion disk analyses are presented. We discuss the properties that we have derived for KQ Mon and compare KQ Mon with other nova-like variables viewed at low inclination. This work was supported in part by NSF grant AST0807892 to Villanova University.

338.07

Far Ultraviolet Spectroscopy of Three Long Period Nova-Like Variables, V363 Aur, AC Cnc and RZ Gru Alexandra Bisol¹, E. M. Sion¹

¹Villanova University.

Exhibit Hall

We have selected three nova-like variables: V363 Aur, RZ Gru and AC Cnc, all of which are UX UMa types, having similar orbital periods well beyond the 3 to 4 hour range where most nova-likes are found. All should have very similar secondary stars given the fact that they their physical parameters are so similar. V363 Aur is a bona fide SW Sex star, and AC Cnc is a probable one, while RZ Gru is not a member of the SW Sex subclass. Our objective is to carry out the first synthetic spectral analysis of far ultraviolet spectra of the three systems using state-of-the-art models both of accretion disks and photospheres. Therefore we shall compare the distances we obtain from the best fitting synthetic spectral models to other distance estimates in the literature. We present model-derived accretion rates and distances for all three systems. The FUV flux range of RZ Gru and V363 Aur is dominated by radiation from an optically thick, steady state, accretion but for AC Cnc, we find that a hot white dwarf accounts for ~ 70% of the FUV flux. We compare the FUV characteristics and physical properties of these three long period nova-like systems to the properties of other nova-likes at shorter periods.

This work was supported in part by NSF grant AST0807892 to Villanova University.

338.08

On The Hot Component Of The Supersoft X-ray Binary/Symbiotic Variable AG Dra Jackeline Moreno $^{\rm 1}$

¹Villanova University.

Exhibit Hall

AG Dra is a D-Type Symbiotic consisting of a metal-deficient K0-4 giant and a hot white dwarf with an orbital period $P_{orb} \sim 550$ days

The outburst recurrence time of AG Dra is every ~ 15 years and the duration of the outbursts is 3 - 6 years. From the classification of the giant, a distance of 2.5 kpc has been estimated. The reddening has been estimated to be E(B-V) = 0.05. Greiner et al.(1997) established that the X-ray/FUV flux level of AG Dra is anti-correlated with the optical maxima.

The nature of the hot component (WD + disk?) and rate of accretion has never been determined from synthetic spectral models of high gravity photospheres or optically thick accretion disk models. We have

combined archival FUSE +IUE spectra obtained in the same activity state (quiescence) and orbital phase (0.5) of the system. In our NLTE the model fitting, we fixed the inclination i = 41 degrees, and the white dwarf mass = 0.6 M_{\odot} (log g = 8) consistent with the lower masses inferred for the hot components in other symbiotic systems (Muerset et al.1991).

From the FUSE spectrum alone, with the distance of AG Dra fixed at 2.5 kpc, we obtain a best fit white dwarf model having T_{eff} = 65,000K with a χ^2 = 4.597 and a best fit accretion disk model with [[Unsupported Character - Ṁ]] = 5 × 10⁻⁸ M_☉/yr. If the distance is a free parameter,

then the best fitting accretion disk model (with a chi² = 3.19) corresponds to [[Unsupported Character - Ṁ]] = $10^{-8} M_{\odot}$ /yr.This fit yields a distance of only 640 pc. Our model results for the combined FUSE +IUE spectra are also presented and discussed.

This work was supported in part by NSF grant AST0807892 to Villanova University.

338.09

A Far Ultraviolet Spectroscopic Analysis of the Old Nova Q Cygni

Craig Kolobow¹, E. M. Sion¹

¹Villanova University.

Exhibit Hall

Q Cygni (Nova Cygni 1876) is one of the oldest old novae with a long orbital period of 10.08 hours and spectroscopic peculiarities in the optical including the presence of variable wind outflow revealed by optical P Cygni profiles in the He I lines and Halpha (Kafka et al.2003). There has never been a far UV spectroscopic analysis of this system. Therefore, we have carried out a synthetic spectral analysis of a far ultraviolet IUE archival spectrum of Q Cygni using our optically thick, steady state, accretion disk models and model white dwarf photospheres. We report the results of our spectroscopic analysis and compare the physical parameters we derive with those of other old novae.

We gratefully acknowledge the support of this by NSF grant 0807892 to Villanova University.

338.10

Time-Resolved Photometry of V458 Vul

Samia Bouzid¹, P. Garnavich²

¹*Rutgers University,* ²*University of Notre Dame.*

Exhibit Hall

We observed V458 Vul (Nova Vul 2007) over four nights in June, 2010, nearly three years after its nova outburst. Time-resolved photometry was obtained at the Vatican Advanced Technology Telescope (VATT) on Mt. Graham, Arizona, covering 2 to 4 hour spans with a cadence of 30 sec. The first night of data shows a clear 20 minute periodicity with a 0.1 magnitude amplitude. On subsequent nights, power-spectral analysis continues to show variations with a time scale of 20 minutes, but the irregularity of the signal suggests that this is a quasi-periodic oscillation. The 98-minute orbital period is not evident in our observations. V458 Vul is the central star of a planetary nebula. Combining our CCD images suggests a light echo from the nova outburst is scattering off of material in the nebula to the northwest of the central star. Appreciation goes to the National Science Foundation for supporting this project through the Research Experience for Undergraduates program at Notre Dame.

338.11

The Survival of Accretion Disks in Recurrent Novae Outbursts

Frederick M. Walter¹, A. Battisti²

¹Stony Brook University, ²University of Massachusetts.

Exhibit Hall

Optical spectra of the emission lines in a sample of 6 recent novae (the recurrent novae YY Dor, N LMC 2009, and U Sco, and the He-Ne novae DE Cir, V2672 Oph, and KT Eri) show Balmer lines consisting of a

broad pedestal of emission with a narrower superposed central emission component. While the broad pedestal is generally modelled as an expanding equatorial torus, we argue that it arises in an accretion disk that either survives the explosion or reconstitutes itself within a day or so of the explosion. The velocities are comparable to those expected from an inner disk radius near the surface of a near-Chandrasekhar-mass white dwarf. We will present time-resolved spectra of these novae, taken with the SMARTS 1.5m telescope at Cerro Tololo.

338.12

Observations of the 2010 January Outburst of the Recurrent Nova U Sco using NASA's Swift

Marilyn Moore¹, S. Engelhardt¹, L. Vega¹, L. McMaster¹, E. M. Schlegel¹, A. Pagnotta² ¹Univ of Texas at San Antonio, ²Louisiana State University.

Exhibit Hall

We report on X-ray observations of the recurrent nova U Sco obtained with NASA's Swift during the 2010 Jan outburst. X-ray spectra were obtained in the 0.1-10 keV band at least once per day throughout the outburst which commenced on 2010 Jan 28 and lasted ~70 days. We fit the spectra with an absorbed, low-order continuum component; the fits yield an integrated X-ray luminosity, the interstellar absorption column, and a pseudo-temperature derived from the continuum parameter. We describe the overall evolution of the X-ray flux as well as the absorption and temperature across the burst.

338.13

X-ray Eclipses in the 2010 January Outburst of the Recurrent Nova U Sco?

Laura McMaster¹, L. Vega¹, M. Moore¹, S. Engelhardt¹, E. M. Schlegel¹, A. Pagnotta² ¹Univ of Texas at San Antonio, ²Louisiana State University.

Exhibit Hall

The recurrent nova U Sco is an eclipsing system with an orbit inclination of 80-83 degrees and for which the secondary blocks the light from the primary for ~0.1 of the orbit in the optical. A clean test of the origin of the X-ray flux in the burst is made possible by U Sco: if X-rays arise from the proximity of the white dwarf, then we must detect X-ray eclipses and the exact shape of the eclipse determines the nature of the distribution of emitting matter. We describe the comparison of X-ray spectra obtained in and out of eclipse.

338.14

The 2010 Eruption of the Recurrent Nova U Scorpii

Ashley S. Pagnotta¹, B. E. Schaefer¹, A. U. Landolt¹, J. L. Clem¹, E. M. Schlegel², K. L. Page³, J. P. Osborne³, G. Handler⁴, F. M. Walter⁵, B. Allen⁶, T. Krajci⁶, B. Monard⁶, R. D. Rea⁶, T. Richards⁶, G. Roberts⁶, W. Stein⁶, C. Stockdale⁶, J. McCormick⁶, S. Dvorak⁷, T. Gomez⁷, B. G. Harris⁷, A. Henden⁷, G. Sjoberg⁷, T. G. Tan⁷, M. Templeton⁷, A. Oksanen⁸

¹Louisiana State University, ²The University of Texas at San Antonio, ³University of Leicester, United Kingdom, ⁴University of Vienna, Austria, ⁵Stony Brook University, ⁶Center for Backyard Astrophysics, ⁷American Association of Variable Star Observers, ⁸Caisey Harlingten Observatory, Finland. Exhibit Hall

We report on the 2010 eruption of the recurrent nova U Scorpii. This outburst was predicted in 2005 and discovered independently by AAVSO observers Barbara G. Harris and Shawn Dvorak on 28 January 2010 as a result of a monitoring program coordinated by our group at LSU in conjunction with the AAVSO. The eruption lasted approximately 64 days, over the course of which more than 35,000 prearranged and serendipitous observations were made in all wavelengths from radio to X-ray. We present multi-wavelength light curves (UBVRIJHKby+UV+X-ray) of the entire eruption which show the overall speed of the event, the expected first plateau, the unexpected second plateau, and the return to quiescence. As anticipated, the onset of the optical plateau coincided with the turn-on of the supersoft X-ray emission and the reemergence of the eclipses. Our comprehensive coverage shows fine-scale phenomena as well, such as flares of up to 0.5 mag in amplitude during the initial fast decline which are as yet unexplained and late aperiodic dips (distinct from the well-known eclipses) that are likely caused by raised rims on the re-forming accretion disk. Additionally, we present outburst spectra showing unusual features such as very high expansion velocities (on the order of 10,000 km/s) and castellated (triple-peaked) Balmer line profiles. This work was funded in part by NSF Grant AST-0708079.

338.15

COS and FUSE Observations of the Post-AGB Star Barnard 29 in M13

William Van Dyke Dixon¹, P. Chayer², B. Y. Welsh³, J. C. Green⁴

¹Johns Hopkins University, ²STScI, ³Space Sciences Laboratory, University of California, ⁴University of Colorado.

Exhibit Hall

We present an analysis of the far-ultraviolet spectrum of the post-AGB star Barnard 29 in the globular cluster M13 (NGC 6205) obtained with COS and FUSE. The data extend from the Lyman limit to about 1780 A with a spectral resolution R \sim 20,000. Previous observers have derived the star's effective temperature (T_{eff} = 20,000 K), surface gravity (log g = 3.0), and abundances of He, C, N, O, Mg, Si, Al, S, and Fe. In addition to these species, we detect absorption from the light elements P and Cl, the iron-peak elements Ti, Cr, and Ni, and the heavy elements Ge and Zr. Using LTE and NLTE stellar atmosphere models, we derive the abundances of these elements and set upper limits for several more. Our Ge and Zr abundances will provide useful constraints on models of nucleosynthesis in AGB stars. This work is supported by NASA grant NNX08AC14G.

338.16

An Imaging Spectral Line Survey of IRC+10216 using the Expanded Very Large Array (EVLA) Mark J. Claussen¹, EVLA Scientific Commissioning Team

¹NRAO.

Exhibit Hall

The Expanded Very Large Array (EVLA) is currently undergoing scientific commissioning, with full scientific operations expected in 2013. During the commissioning, we have performed a rather coarse (~25 km/s) and shallow imaging spectral survey of the circumstellar environment of the well-known and nearby carbon-rich asymptotic giant branch (AGB) star IRC+10°216 (CW Leo) in the frequency range 18 - 26.5 GHz, using the capability of the WIDAR correlator to simultaneously observe 2 GHz of bandwidth. In addition we have used the additional capability of WIDAR to observe widely spaced sub-bands to observe eight pairs of targeted lines with much better spectral resolution (1.0 - 2.0 km/s) in the 18 - 26.5 GHz receiver band (selected from the coarse survey) and the 26.5 - 40 GHz receiver band (selected from the single-dish survey of Kawaguchi et al. (1995, PASJ, 47, 853). In the coarse survey, we detected twenty-one transitions of eleven molecules including eight transitions of HC₇N, ranging from 18.049 GHz to 25.946 GHz, the J = 1 - 0 maser transition of SiS at 18.156 GHz, and three transitions of HC₅N. We will present further results of the survey and images of the emission from the targeted lines. The National Radio Astronomy is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

Testing 3D SPH Models Of Eta Carina's Winds By HST, RXTE, VLT And VLTI Observations

Theodore R. Gull¹, T. Madura², J. Groh², G. Weigelt², M. Corcoran³, S. Owocki⁴, C. Russell⁴, A. Okazaki⁵ ¹NASA/GSFC, ²MPIR, Germany, ³USRA@GSFC, ⁴U. Del, ⁵Hokkai-Gakuen University, Japan. Exhibit Hall

Observations of Eta Carina have been combined with three-dimensional smoothed-particle hydrodynamic (3DSPH) simulations providing considerable insight on this >100 Mo binary that may become near-term supernovae, a GRB, or a staid WR binary. Understanding how this system loses 1e-3 Mo/yr, 500 km/s will provide new understanding of massive stellar evolution, including the first progenitors of GRBs, supernovae and pseudo-supernovae.

The 3DSPH models extend to 100 semi-major axes (~2000 AU, <2" at 2300 pc). At these scales, HST/STIS resolves [Fe III] and [Fe II] spatial-velocity structures that change with orbital phase and position angle. Radiative transfer models combining temperature and density with EtaCar B's FUV lead to synthetic spectroimages of extended wind-wind interfaces. Model X-ray light curves provide orbital inclination and location of periastron but cannot determine sky PA. Synthetic spectro-images generated for a range of possible binary orientations lead to best-fit when the orbital axis is closely aligned with the Homunculus axis of symmetry, and periastron with EtaCar B on the far side of EtaCar A. VLTI/AMBER measures of the continuum, extended hydrogen and helium structures of EtaCar A demonstrate that, across periastron, EtaCar B penetrates the primary extended atmosphere. Spectroimagery observations of He 10830 by VLT/CRIRES show blue-shifted emission extending to -1500 km/s, consistent with wind-wind structures driven by the companion's fast wind.

The 2009.0 RXTE X-ray recovery and return of the spectroscopic high state was much sooner than the 1998.0 and 2003.5 recoveries. What has changed? Suggestions range from a drop in the primary wind, changes in the secondary wind or line-of-sight shifting of the wind-wind boundary. We will discuss potential observational tests based upon predictions by 3DSPH models.

338.18

Locations of Luminous Blue Variables in Host Clusters

Michelle L. Edwards¹, R. M. Bandyopadhyay², S. S. Eikenberry² ¹*Gemini Observatory, Chile,* ²*University of Florida.*

Exhibit Hall

We review the current body of literature concerning the environments of Luminous Blue Variables (LBVs), focusing on five LBVs and LBV candidates located in young massive clusters. Although mass segregation theories suggest that these massive stars should be located in the cores of their natal clusters, our analyses reveal that four out of five of these rare, massive objects lie on the outskirts of their hosts and that chance alone cannot account for this anomaly. We discuss the impact of this finding on massive star and star cluster formation theories and propose future work that may increase the number of LBVs with established membership in a cluster.

338.19

New X-ray Detections Of Late Nitrogen-type (WNL) Wolf-Rayet Stars

Steve L. Skinner¹, M. Guedel², W. Schmutz³, S. Zhekov⁴

¹Univ. Of Colorado, ²Univ. Of Vienna, Austria, ³PMOD/WRC, Switzerland, ⁴JILA, Univ. Of Colorado. Exhibit Hall

We present results of recent X-ray observations of nitrogen-type Wolf-Rayet (WR) stars, focusing on late WN7 - WN9 subtypes. These observations were obtained as part of a broader X-ray survey of single WN stars using XMM-Newton and Chandra aimed at determining their X-ray properties and identifying plausible emission mechanisms. None of the WN survey targets is known to be a member of a binary

system. We report unambiguous detections of WR 78 (WN7h) and WR 79a (WN9ha), and a possible (faint) detection of WR 16 (WN8h). These new WNL detections, along with previous detections of WN2 - WN6 stars, demonstrate that WN stars are X-ray sources across their full range of spectral subtypes. The X-ray luminosities of WN stars span a broad range (even among stars of similar spectral subtype) with typical values log Lx = 31.5 - 33.5 (ergs/s). There is some evidence that Lx is proportional to wind kinetic energy. WN star X-ray spectra show higher absorption than expected from optical extinction, likely due to their powerful metal-rich winds. Their spectra reveal strong emission lines from ionized metals and spectral fits typically require two components consisting of cool (kT < 1 keV) and hot (kT > 2 keV) plasma. Only cool plasma is anticipated if the X-rays arise in radiative wind shocks, so the presence of hot plasma implies other as yet unidentified X-ray production mechanisms are at work. Magnetic fields may play a role, but in contrast to magnetically-active solar-like stars, WN stars do not show large-amplitude X-ray flares in observations typically spanning a half day. But, more extensive monitoring at higher time-resolution is needed. Alternatively, unseen companions at close separation could play a role in WN star X-ray emission in some cases (esp. higher Lx objects), either via their intrinsic emission or as colliding wind secondaries.

338.20

Modeling The Variation Of X-rays From Wolf-rayet Stars Michael McFall¹, R. Ignace²

¹Butler University, ²East Tennessee State University. Exhibit Hall

Wolf-Rayet (WR) stars are massive stars with powerful, x-ray-emitting winds. Some single stars have been observed to have a periodic behavior. A model using a spiral structure in the winds has been created to explain what causes this variability. We used this model to examine the possibility of x-ray variation in single WR stars. We have then used the model to determine probabilities of finding before unknown variation in the x-rays of single WR stars given a set of parameters that define the spiral structure and the properties of the wind.

This project was funded by the National Science Foundation Research Experiences for Undergraduates (REU) program through grant NSF AST-1004872.

339 *Circumstellar Disks* Poster Session *Exhibit Hall*

339.01

Discovery of an Extended Halo in the Fomalhaut Debris System Pablo Espinoza¹, K. Su¹, G. Rieke¹, K. Stapelfeldt² ¹Steward Observatory, University of Arizona, ²Jet Propulsion Lab. Exhibit Hall

Fomalhaut, a bright A3V star located 7.7 pc away, is a particularly interesting system for the study of planetary formation and evolution because it possesses a debris disk and a planet revealed by direct imaging. The whole system provides a unique opportunity to explore the connection between debris disk structure and planetary configuration. In this work we present deep Spitzer MIPS observations of Fomalhaut. The new data combined with detailed models lead to the following conclusions: (1) a confirmation of a central, unresolved warm (~150 K) component, analogous to the asteroid belt, and (2) the dust emission of the cold disk can be traced, at least, to ~700 AU from the star. The measured size is much larger than the previous estimates of the cold outer ring (160-260 AU in radius) from the scattered-light and submillimeter images respectively, suggesting the presence of an extended halo

around the system. The extended halo is likely to originate from small grains that are being ejected and/or on highly eccentric orbits under the influence of radiation pressure. From modelling the surface brightness distributions, we estimate the halo is as bright as 25% of the total emission at 70 um. We also compare these results with the halo in the Vega system to shed light on the different levels of stirring in the parent-body rings.

339.02

Probing for Exoplanets Hiding in Dusty Debris Disks: Inner (<10 AU) Disk Imaging, Characterization, and Exploration

Glenn Schneider¹, HST GO 12228 Team

¹Univ. of Arizona.

Exhibit Hall

We are obtaining HST/STIS observations of a well-selected sample of eleven circumstellar (CS) debris disks, all with HST pedigree, using PSF-subtracted multi-roll coronagraphic imaging. Our observations are probing the interior CS regions of these debris systems (inner working distances &It; approximately 8 AU for half the sample), corresponding to the giant planet and Kuiper belt regions within our own solar system. These images will enable us to: (a) directly inter-compare the architectures of these exoplanetary debris systems in the context of our own Solar System, (b) characterize the material in these regions at high spatial resolution and, (c) look for sub-structures within the disks that are sign posts of planetary formation and evolution; in particular, asymmetries and non-uniform debris structures signaling the presence of co-orbiting perturbing planets. All of our objects were previously observed at longer wavelengths (with lower spatial resolution and imaging efficacy) with NICMOS, but with an inner working angle comparable to STIS multi-roll coronagraphy. The combination of new optical and existing near-IR imaging will strongly constrain the dust properties enabling an assessment of grain processing and planetesimal populations. These results will directly inform upon the posited planet formation mechanisms that occur after the approximately 10 My epoch of gas depletion (a time in our solar system when giant planets were migrating and the terrestrial planets were forming) and directly test theoretical models of these processes. The outer reaches (only) of most of these systems were previously observed with a much larger (\sim 6x on average), spatially limiting, effective inner working angle of the ACS coronagraph and do not reveal the inner structures of these CS disks. Our investigation will uniquely probe into the interior regions of these systems for the first time with spatial resolution comparable to ACS and with augmenting NICMOS near-IR disk photometry in hand.

339.03

Keck Adaptive Optics Imaging of the HD 32297 Debris Disk

Thomas Esposito¹, M. P. Fitzgerald¹, P. Kalas², J. R. Graham²

¹University of California, Los Angeles, ²University of California, Berkeley. Exhibit Hall

We have spatially resolved the debris disk around the A5 star HD 32297 in scattered light using Keck NIRC2 coronagraphic imaging with adaptive optics in the H and K bands. We used angular differential imaging to suppress the stellar PSF and reveal the nearly edge-on disk. Our investigation into the inner structure of the disk seeks to characterize the previously reported brightness asymmetry. This is a key region given the links between extrasolar planets and circumstellar debris disks, and our study benefits from the high angular resolution of Keck adaptive optics. Additionally, our measurement of the disk color can help to constrain the nature and distribution of grains present in the system. This work was supported in part by University of California Lab Research Program 09-LR-01-118057-GRAJ and NSF grant AST-0909188.

Circumstellar Disk Studies with the Gemini Planet Imager: Simulations and Sensitivities

Marshall D. Perrin¹, M. P. Fitzgerald², J. K. Chilcote², S. J. Wiktorowicz³, J. R. Graham⁴, L. Poyneer⁵, B. A. Macintosh⁵, Gemini Planet Imager team

¹STScI, ²UCLA, ³UC Berkeley, ⁴Dunlap Institute, University of Toronto, Canada, ⁵LLNL. Exhibit Hall

The Gemini Planet Imager (GPI), currently under construction for the 8-m Gemini South telescope, will study circumstellar disks using the polarization of scattered starlight. GPI will obtain these observations using a novel "integral field polarimetry" mode, in which the dispersing prism of its integral field spectrograph is replaced by a Wollaston prism, providing simultaneous dual polarimetry for each resolution element in the field of view, with minimal differential wavefront aberrations and thus maximum contrast for detecting faint circumstellar dust. We present end-to-end numerical modeling of adaptive optics and instrument performance demonstrating GPI's high sensitivity to optically thin circumstellar material. GPI is expected to be able to image scattered light from debris disks with significantly lower optical depths than are currently resolvable. Simulated observation sequences, processed through the current draft of GPI's data reduction pipeline, are allowing us to develop optimal observation strategies in preparation for GPI's first light planned for late 2011.

339.05

SEEDS Polarimetric Imagery of the AB Aur Protoplanetary Disk

John P. Wisniewski¹, M. Fukagawa², C. Grady³, J. Hashimoto⁴, K. Hodapp⁵, T. Kudo⁴, M. Munetake⁶, Y. Okamoto⁶, M. Tamura⁴, SEEDS Team

¹University of Washington, ²Osaka University, Japan, ³NASA GSFC/Eureka Scientific, ⁴NAOJ, Japan, ⁵University of Hawaii, ⁶Ibaraki University, Japan.

Exhibit Hall

The Strategic Exploration of Exoplanets and Disks with Subaru (SEEDS) is a large survey which will be observing roughly 200 protoplanetary and debris disk systems over the next five years using the HiCIAO coronagraph + AO188 system on the Subaru telescope. We present new J-band polarimetric differential imagery of the proto-type Herbig Ae star, AB Aurigae, which diagnoses scattered light from the system between 20 - 540 AU at a resolution of roughly 8 AU. We discuss the morphology we observe in the outer disk region in the context of previous observations of the system, and compare/contrast the morphology in the inner disk region with recent H-band imagery of the system made with HiCIAO (Hashimoto et al 2010).

This work was supported in part by NSF grants AST 0802230 and AST 1009314 and the AAS' Chretien International Research Grant.

339.06

A Model of Molecular Emission from Protoplanetary Disks

Samuel Thomas Harrold¹, J. Lacy¹, C. Salyk¹, S. Doty²

¹University of Texas at Austin, ²Denison University.

Exhibit Hall

We present results from a new model describing the mid-infrared emission of simple organic molecules from the protoplanetary disks of low-mass stars. We will test whether indicators of disk evolution, such as grain growth, dust settling, and dust crystallinity, enhance the emission of simple organic molecules in the mid-infrared, in particular that of HCN and C2H2, from the inner few AU of the disk. The Q branches of HCN at 13.9 um and of C2H2 at 13.7 um have been detected in the spectra of disks around T-Tauri stars using Spitzer's IRS (Carr & amp; Najita, 2008). Our new model, pisco, calculates the steady-state disk structure and molecular level populations via non-LTE, 3D radiative transfer. The chemical
abundances are determined through a chemical evolutionary code. This work is supported by the NSF GRFP.

339.07

Induction Heating of Planetesimals in Protoplanetary Disks Raymond L. Menzel¹, W. Roberge¹

¹New York Center for Astrobiology and Department of Physics, Applied Physics, and Astronomy, Rensselaer Polytechnic Institute.

Exhibit Hall

Induction heating is a process originally proposed by Sonett et al. to explain thermal processing of asteroids, some of which were heated to temperatures >1000 K in the solar nebula. In the scenario of Sonett et al., the asteroids were heated during the Sun's T Tauri phase by a dense, fully-ionized solar wind. In their view an asteroid exposed to such a wind would "see" a motional electric field E=-v/c x B, where v is the wind velocity and B is the magnetic field in the wind's rest frame. If correct, the resulting electric polarization of the asteroidal material would produce electrical currents and heating via Ohmic dissipation. We revisit the induction heating mechanism to assess its possible relevance to planetesimals in weakly-ionized protoplanetary disks, where large magnetic fields of 0.1-1 G are predicted on a variety of grounds. Due to the high densities of these disks, we adopt a fluid approach for the plasma. We point out that E=-v/c x B is strictly speaking the electric field far from a planetesimal, where the plasma streams freely. At the planetesimal surface, viscous forces in a shear layer bring the plasma to rest and the motional electric field vanishes. We show that there is nevertheless a nonvanishing electric field produced indirectly via magnetic field perturbations in the shear layer. We calculate these perturbations by solving the equations of nonideal MHD, including Ohmic dissipation, the Hall effect, and ambipolar diffusion. We use these results to find the electric field in- and outside a planetesimal and give quantitative estimates of the rates of heating by Ohmic dissipation, viscous dissipation, and energy dissipation associated with ambipolar diffusion.

339.08

Sublimation of Icy Planetesimals Around Main Sequence Stars--Common Dust Temperatures & Multiple Components

Farisa Y. Morales¹, G. Rieke², M. Werner¹, K. Su², G. Bryden¹, K. Stapelfeldt¹

¹JPL, ²UofA.

Exhibit Hall

We compare the properties of warm dust emission from main-sequence A-type stars to those of dust around solar-type sources with similar Spitzer Space Telescope IRS/MIPS data and similar ages. Both samples have spectral energy distributions which show evidence of multiple components. Over the range of stellar types considered, we obtain nearly the same characteristic dust temperatures (~190 K & ~55 K for the inner & outer dust components respectively)--just above the ice line for the inner belts. The inner-belt temperature is readily explained if populations of grains are being released by sublimation of ice from icy planetesimals. Evaporation of comets at ~170 K transports particles into an inner/warmer belt, where the super thermal grains left behind are found with Tdust >=190 K. 27 of the 50 A-type sources with warm excess are detected with Spitzer/MIPS at 70 μ m (S/N > 3); the ~50% rate of detection is comparable to the solar-type star sample where 9 of the 19 objects are also seen at MIPS 70 μ m.

This work is based on observations made with the Spitzer Space Telescope, which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under NASA contract 1407. Development of MIPS was funded by NASA through the Jet Propulsion Laboratory, subcontract 960785. This work was also partially supported by contract 1255094 from Caltech/JPL to the University of Arizona.

The Nature of Transition Disks in Nearby Star-forming Regions

Lucas A. Cieza¹, M. R. Schreiber², G. A. Romero², M. Orellana², J. P. Williams¹, B. Merin³ ¹University of Hawaii, ²Universidad de Valparaiso, Chile, ³European Space Agency (ESA-ESAC), Spain. Exhibit Hall

We present an update on our ongoing project to characterize a large sample of Spitzer selected transition disks located in several star-forming regions. Transition objects are pre-main-sequence stars with optically thin inner disks and optically thick outer disks. Different mechanisms have been proposed to explain their inner opacity holes: planet formation, grain growth, photoevaporation, and tidal truncation in tight binaries. These mechanisms, all relevant to disk evolution in general, can be distinguished when disk masses, accretion rates, and multiplicity information are available. We have already completed our study of Ophiuchus objects, presenting the results from Adaptive Optics (AO) imaging, submillimeter photometry, and echelle spectroscopy observations. We are currently working on several other regions, including Taurus-Auriga, Perseus, Serpens, and Lupus. Our results show that transition disks are a very heterogeneous group of objects with a wide range of SED morphologies, disk masses (< 0.5 to 40 M_{jup}), and accretion rates (<10E–11 to 10E–7 M_{solar}/yr). Since the properties of our transition disks point toward distinct processes driving the evolution of each disk, we have been able to identify very strong candidates for the following disk categories: circumbinary disks, grain-growth dominated disks, photoevaporating disks, debris disks, and (giant) planet-forming disks.

339.10

Truncation of Circumplanetary Discs by Tidal Torques

Rebecca G. Martin¹, S. H. Lubow¹

¹STScI.

Exhibit Hall

We model circumplanetary discs as accretion discs subject to the tidal forces of the central star. The tidal torques remove the disc angular momentum near the disc outer edge and permit the accreting disc gas to lose angular momentum at the rate appropriate for steady accretion. Circumplanetary discs are truncated near the radius where periodic ballistic orbits cross, where tidal forces on the disc are strong. This radius occurs at approximately 0.4 times the planet Hill radius. During the T Tauri stage of disc accretion, the disc is fairly thick with aspect ratio H/r>0.2. We model the disc structure using one-dimensional time-dependent and steady-state models and also two-dimensional SPH simulations. The circumplanetary disc structure depends on the variation of the disc turbulent viscosity with radius and is insensitive to the angular distribution of the accreting gas. If the disc is turbulent throughout, the predicted disc structure near the location of the regular Jovian and Saturnian satellites is smooth with no obvious feature that would favor formation at their current locations.

339.11

Detection Of Exocomets Within Edge-on Debris Disks

Sharon Lynn Montgomery¹, B. Welsh²

¹Clarion University, ²UC Berkeley, Space Sciences Laboratory. Exhibit Hall

The youngest circumstellar debris disks in orbit around main sequence stars are thought to represent the last stage in the formation of a planetary system. Dust and gas continues to be replenished in these systems when planetesimals reach sizes of around 2000 km. Dynamical instabilities can "stir" the population of smaller planetesimals such that they undergo violent dust-generating collisions with each other. The same instabilities may send comets on highly eccentric orbits toward the star in these debris disk systems. Four stars, including the protypical debris disk star Beta Pic, have already been shown to exhibit short-term (i.e., night-to-night) variability in Ca II, which is widely believed to be due to infalling evaporating bodies (FEBs or exocomets).

We have collected moderately high-resolution spectra of ten young, A-type, rapidly-rotating stars with excess infrared continuum emission using the Cassegrain-Echelle spectrograph of the 2.1m Otto Struve Telescope. Here, we report the detection of two new gas disk systems with short-term variability in Call: 5 Vul and 49 Cet. While the circumstellar disks of both stars have been previously described in the literature, this is the first report of night-to-night variability within the debris disk gas. Velocity arguments have allowed us to place some constraints on the dynamics of the absorbing gas.

339.12

Rotation and Circumstellar Disks in the Upper Scorpius OB Association

Scott E. Dahm¹, C. L. Slesnick²

¹W. M. Keck Observatory, ²Charles Stark Draper Laboratory.

Exhibit Hall

We present projected rotational velocities for 20 early-type (B8-A9) and 53 late-type (F3-M8) members of the 5 Myr old Upper Scorpius OB Association determined using high-resolution optical spectra obtained with HIRES on Keck I and MIKE on the Magellan Clay telescope. The Upper Scorpius sample is composed of primordial and debris disk systems as well as non-excess sources. We combine the derived rotational velocities with *Spitzer Space Telescope* IRAC 4.5 and 8.0 µm fluxes and MIPS 24.0 µm photometry in order to examine the influence of circumstellar disks upon stellar and substellar rotation. Preliminary results using non-parametric statistical tests suggest that the late-type disk-bearing members of Upper Scorpius rotate more slowly than their non-disk counterparts at a high confidence level. Among the early-type Upper Scorpius members, however, the rotational velocities of the debrisdisk and non-disk populations are indistinguishable. We also compare the rotational velocities of the Upper Scorpius sample with those of similar sources in Taurus-Auriga, where stars may not have had sufficient time to undergo disk-braking.

339.13

The Far-uv ``continuum" In Protoplanetary Disks: Accretion, H2, And Co

Kevin France¹, H. Yang¹, J. L. Linsky¹, G. M. Harper², E. Schindhelm¹, A. Brown¹, G. J. Herczeg³ ¹University of Colorado, ²Trinity College, Ireland, ³Max-Planck-Institut fur extraterrestriche Physik, Germany.

Exhibit Hall

We present new far-UV spectroscopic observations of a sample of classical T Tauri stars obtained with the HST-Cosmic Origins Spectrograph. The combination of very low background and moderate spectral resolution allow us to unambiguously measure the processes that contribute to the far-UV continuum emission in these systems: hot chromospheric accretion, electron-excited H2, and CO A-X band emission. Previous observations have lacked the sensitivity to detect this faint emission or the spectral resolution to study the composition of this ``continuum'' in detail. We show that the accretion spectrum can be fit in a continuous manner from the far-UV to the optical in some systems. The far-UV spectrum of CO has been identified and modeled for the first time in a protostellar/protoplanetary disk. The electron impact spectrum of H2 has been modeled, and results indicate that the red far-UV color ratio and attenuation of discrete Werner band features is consistent with absorption by hydrocarbons in the inner disk.

Spectral Analysis of Mid-IR Excesses of WDs

Jana Bilikova¹, Y. Chu¹, K. Su², R. Gruendl¹

¹Univ. of Illinois at Urbana-Champaign, ²University of Arizona.

Exhibit Hall

In our Spitzer 24 um survey of hot white dwarfs (WDs) and archival Spitzer study of pre-WDs, i.e., central stars of planetary nebulae (CSPNs), we found mid-IR excesses for ~15 WDs/pre-WDs. These mid-IR excesses are indicative of the presence of circumstellar dust that could be produced by sub-planetary objects. To further assess the nature of these IR-excesses, we have obtained Spitzer IRS, Gemini NIRI and Michelle, and KPNO 4m echelle spectra of these objects. We present the analysis of these spectroscopic observations and discuss the nature of these IR excesses.

339.15

Radial Distribution of Molecules and Ions in the Protoplanetary Around IM Lup Brian E. Svoboda¹, K. I. Oberg²

¹Western Washington University, ²Harvard Smithsonian Center for Astrophysics. Exhibit Hall

We present spatially and spectroscopically resolved Submillimeter Array (SMA) observations of 12CO J=2-1, 13CO J=2-1, DCO+ J=3-2, N2H+ J=3-2, and H2CO J=4(14)-3(13) line emission from the IM Lup protoplanetary disk. We use Monte Carlo radiative transfer calculations to compare the SMA visibilities with tapered disk models, and use the results to constrain the outer radii of the emission regions. N2H+ and H2CO are proposed to trace dust grains at temperatures below 20 K, and DCO+ is proposed to trace gas temperatures below 40 K. The inferred outer radii for N2H+ and H2CO are both 600 AU, and 300-600 AU for DCO+. These values are consistent with thermally decoupled gas and dust in the outer disk. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 0754568 and by the Smithsonian Institution.

339.16

Hα Emission vs. Continuum Variability of MWC349A

Kamber R. Schwarz¹, V. Strelnitski², G. Walker²

¹U. of Arizona & Maria Mitchell Obs, ²Maria Mitchell Obs.. Exhibit Hall

We report on a three-year CCD monitoring of MWC349A at the Maria Mitchell Observatory with narrowband and broadband filters. The use of three narrowband filters centered on H α and adjacent continuum allowed us to separate, for the first time, the variability of this object's H α emission from that of the continuum. We detected a general anticorrelation of H α emission with its nearby continuum and, tentatively, periodic variations of the H α flux with a period of 223±7 days and a peak-to-peak amplitude of $\approx 6\%$. This period is close to the supposed period of 238±8 days for the variations of the peak ratio of the double-peak spectrum of the masing H30 α line (Fuchs et al. 2010). More observations, both in the optical and radio domains, are needed to verify these new phenomena. We briefly discuss possible causes of the periodicity and the anticorrelation between the H α emission and continuum. This project was supported by NSF/REU grant AST-0851892 and the Nantucket Maria Mitchell Association.

339.17 Probing the Massive Primordial Disks around Two Low Mass Stars Breann Sitarski¹, C. Melis¹

¹UC San Diego. Exhibit Hall

Low mass stars are the dominant stellar constituent in our Galaxy and likely the typical planet-hosting stars. Yet, our understanding of how protoplanetary disks evolve and give rise to planetary systems around such stars is incomplete. We have identified two young, very dusty early- to mid-M type stars. Optical and near-infrared spectroscopy of each source confirms their youthful ages and late spectral types. These low mass stars host massive primordial disks as determined through mid- to far-infrared photometric measurements and preliminary disk modeling for each system. Eventual detailed models of both systems will increase the small sample size of well-characterized protoplanetary disks orbiting low mass stars.

339.18

First Detection of Both Absorption and Emission of Molecular Hydrogen in Classical T Tauri Stars Jeffrey Linsky¹, H. Yang¹, K. France²

¹JILA, Univ. of Colorado and NIST, ²CASA, Univ. of Colorado.

Exhibit Hall

Classical T Tauri stars (CTTSs) show bright emission lines of molecular hydrogen in their ultraviolet spectra. These fluorescent emission lines are pumped by molecular hydrogen transitions coincident with the hydrogen Lyman-alpha emission line and other UV emission lines. While these emission lines have been studied in the UV spectra of many CTTSs, the pumping transitions have never been detected in absorption against the Lyman alpha emission line. Spectra obtained with the excellent sensitivity and low background of the new Cosmic Origin Spectrograph (COS) on HST now show absorption by the pumping transitions in two CTTSs, V4046 Sag and DF Tau. We compare the energy absorbed in each pumping transition to the energy emitted in the resulting fluorescent emission lines. The absorption/emission ratios are very different from unity, but the ratios at different wavelengths across the Lyman-alpha emission line of each star can be brought close to unity by assuming additional Lyman-alpha absorption along the line of sight. For V4046 Sag, a CTTS observed nearly face-on, the required absorption is near +290 km/s most likely due to hydrogen accreting onto the star. For DF Tau, a CTTS observed nearly edge-on, the line of sight absorption is near 0 km/s, indicating absorption in the disk. We shows models for both stars.

This work is supported by a NASA grant to the University of Colorado.

339.19

Remnant Protoplanetary Disks Around Weak-Lined T Tauri Stars Elise Furlan¹

¹JPL, Caltech.

Exhibit Hall

Nascent stars are surrounded by circumstellar disks for several Myr; it is material from these disks that adds mass to the star and also leads to the formation of planetary systems. Over time, the mass accretion rate from the disk onto the star decreases, and various mechanisms will disperse the dust and gas in the disk. At the end of this evolutionary sequence, it is thought that a pre-main-sequence star becomes a weak-lined T Tauri star (WTTS), which lacks signatures of accretion and typically also an infrared excess, implying that the dust and gas have dissipated. However, there are WTTS with infrared excesses of varying strength, which suggests that some disk material is still present. These objects are ideal for studying the late stages of disk dissipation, which are crucial for understanding and

constraining planet formation.

Here we present an analysis of such objects using mid-infrared spectra obtained with the Infrared Spectrograph on the Spitzer Space Telescope. We characterize the infrared excess and thus the degree of dust depletion in these systems, derive the distribution and composition of the remaining dust, and compare these quantities with system properties, such as spectral types and disk masses. Our study will shed light on the conditions of remnant protoplanetary disks and the final disk dissipation mechanisms. This work is supported by NASA through the Spitzer Space Telescope Fellowship Program, through a contract issued by JPL/Caltech under a contract with NASA.

339.20

Hot Inner Gas Disks Around A-type Stars Kwang-Ping Cheng¹, J. E. Neff²

¹Cal. State Univ., Fullerton, ²College of Charleston. Exhibit Hall

Since the IRAS discovery of Vega's large thermal infrared excess over the expected photospheric flux, dust disks have been found around a large fraction of main-sequence A-type stars. With the detection of gas giant planets orbiting Alpha PsA, Beta Pic, and HR 8799, we now have evidence that A-type stars can host planetary systems. While dust in A-type star debris disks has been studied extensively with Spitzer, relatively little is known about their connection with circumstellar gas. Circumstellar gas is often observed in debris disk systems, but it is also observed in many A-type stars without debris disks. We have used high-resolution optical and ultraviolet absorption spectroscopy to detect circumstellar gas around nearby A-type stars, but there are still many unanswered questions. What is the origin of the observed circumstellar gas? Is it a gas disk or a gas shell (or both)? Is the gas a remnant of star formation? In the spectra of some A-type dwarfs, three Ti II transitions (3685, 3759, 3761 Å) sometimes appear as narrow absorption lines. These Ti II lines can be used as an additional diagnostics for the origin of the hot inner gas.

339.21

The Variable Circumstellar Disk of the Classical Be Star theta CrB

Tiffany Pewett¹, K. S. Bjorkman¹, J. W. Davidson, Jr.¹

¹University of Toledo.

Exhibit Hall

Classical Be stars have circumstellar disks that produce hydrogen and helium emission lines in their spectra. The formation mechanism for these disks is still poorly understood. One known contributing factor is the fact that these stars are rapidly rotators. There must be other factors however, considering that not all rapidly rotating stars have disks, and in those that do, the disks are known to disappear and reform seemingly randomly. theta Corona Borealis is one such example of a star with a variable disk; however, it has not been well studied over cycles of disk loss and formation. It is believed that its disk faded away in 1970 when the star's apparent magnitude decreased by about fifty percent of its normal brightness. In 2006, the disk started reforming slowly, and then began fading again. In order to understand the underlying mechanism for disk loss and rebuilding, it is important to have information about the timescales for these processes. To that end, we have analyzed the available spectroscopic data collected over a number of years at the Ritter Observatory to determine when, and possibly why, the disk disappeared and is now trying to redevelop. We present our results so far, which have proven to be interesting, and describe our ongoing work to attempt to gain a better understanding of the process that the star is undergoing.

This work has been supported by an NSF REU grant to the University of Toledo.

Disk-Loss and Disk Renewal Phases in Classical Be Stars III. Modeling Effects of Disk Structure

Zachary H. Draper¹, J. P. Wisniewski¹, K. S. Bjorkman², X. Haubois³, A. C. Carciofi³, J. E. Bjorkman², M. R. Meade⁴

¹University of Washington, ²University of Toledo, ³Universidade de São Paulo, Brazil, ⁴University of Wisconsin.

Exhibit Hall

In Wisniewski et al. 2010, paper I, we analyzed 15 years of spectroscopic and spectropolarimetric data from the Ritter and Pine Bluff Observatories of 2 Classical Be stars, 60 Cygni and π Aquarii. During this time both stars underwent a transition from Be to B star, whereby they lost their circumstellar disks. Since the mechanism for feeding these disks is not known, observing these stars when they transition between a Be phase and a normal B star phase can help constrain what leads to the disk growth and dissipation. Here we analyze the detailed behavior of the intrinsic polarization, and detect loop-like structures caused by the rise and fall of the polarization Balmer Jump and continuum V-band polarization being mismatched temporally during polarimetric outbursts. We demonstrate how these clockwise loops provide a unique diagnostic of the inner regions of these disks. We also see polarization angle deviations from the mean, reported in paper I, which may be indicative of warps in the disk, blobs being injected into the disk, or spiral density waves. We incorporate several types of disk structure to a 3D NLTE Monte Carlo radiation transfer code, such as blobs, rings, and scale height variations, to explore the origins causing the observed PA variations as well as their effect on the Balmer jump vs V-band polarization loops.

339.23

A Comparison of Methods of Measuring Be Star Disks

Erika Grundstrom¹, D. R. Gies²

¹Vanderbilt University, ²Georgia State University.

Exhibit Hall

Be stars are rapidly rotating B-type stars that lose mass in an equatorial, circumstellar disk (Porter & amp; Rivinius 2003). A fundamental measurement Be star observers desire is the size of this circumstellar disk. We present a comparison of the Grundstrom & amp; Gies (2006) method using the equivalent width of H-alpha and the Huang (1972) method of using peak separation. We discuss dependences on temperature and inclination as well.

339.24

The Delta Scorpii Be Binary. The Disk Development and Periastron 2011.

Anatoly S. Miroshnichenko¹, S. Stefl², N. Manset³, K. S. Bjorkman⁴, M. Korpela⁴, J. Davidson⁴, T. Rivinius², A. T. Okazaki⁵, A. C. Carciofi⁶, E. Pollmann⁷, B. Heathcote⁸, H. Levato⁹, M. Grosso⁹, J. Fabregat¹⁰, S. V. Zharikov¹¹

¹Univ. of North Carolina at Greensboro, ²Eropean Sothern Observatory, Chile, ³Canada-France-Hawaii Telescope Corporation, ⁴Univ. of Toledo, ⁵Hokkai-Gakuen University, Japan, ⁶Univ. of Sao Paulo, Brazil, ⁷ASPA-Arbeitsgemeinschaft, Germany, ⁸Barfold Observatory, Australia, ⁹CASLEO, Argentina,

¹⁰Observatorio Astronómico de la Universidad de Valencia, Spain, ¹¹Univ. Nacional Autónoma de México, Mexico.

Exhibit Hall

Delta Scorpii is a bright (V=2.3 mag) binary system with a B0-type primary and supposedly a B-type secondary at an

eccentric orbit (e=0.94). A brightening detected in the summer of 2000 marked the beginning of a circumstellar disk

formation around the primary component. It occurred a few months before the periastron which was detected through a strong radial velocity change in September 2000. We present a history of the disk development and discuss possible explanations for the observed variations of the optical and near-infrared brightness and emission line profiles. The next periastron is predicted to occur in early July 2011. We emphasize the importance of frequent observations of Delta Scorpii with various techniques in 2011, predict some phenomena that may occur near periastron, and suggest observing strategies.

340

YSOs, Very Young Stars and Friends Poster Session *Exhibit Hall*

340.01

Near-infrared Spectroscopy of KH 15D

Josh Sokol¹, W. Herbst², J. P. Emery³, M. S. Connelley⁴, C. M. Hamilton⁵, C. M. Johns-Krull⁶, R. Mundt⁷ ¹Swarthmore College, ²Wesleyan Univ., ³Univ of Tennessee, ⁴Institute for Astronomy, U. of Hawaii, ⁵Dickinson College, ⁶Rice University, ⁷Max-Planck-Institute for Astronomy, Germany. Exhibit Hall

We present 0.8 - 2.5 μ m spectroscopy of the variable young stellar object KH15D at two stages of occultation by its circumbinary disk. We confirm the presence of molecular hydrogen emission at 2.12 μ m, and report the discovery of He I emission at 1.08 μ m. Flux measurements of these lines indicate that the He I emission is suppressed as the star sinks lower behind the disk, while flux from the more spatially diffuse molecular hydrogen remains constant. The spectra also show that KH15D reddens as it moves deeper into eclipse. Support from NASA through its Origins of Solar Systems program is gratefully acknowledged. One of (J.S.) was supported by an NSF/REU grant to Wesleyan University in support of the Keck Northeast Astronomy Consortium.

340.02

Recent Near-Infrared Photometry of KH 15D: the Eclipses have Ended but Significant Light Variations on the Orbital Period Continue

William Herbst¹, A. Bennett², C. Hamilton³

¹Wesleyan Univ., ²Middlebury College, ³Dickinson College.

Exhibit Hall

VIJH photometry of the formerly eclipsing binary T Tauri system KH 15D has been obtained with the SMARTS 1.3m telescope at CTIO covering the period since the eclipses have ended. As is seen in the optical, large amplitude variations on the orbital period continue in J and H but do not have the character of an eclipse. These are attributed to changes in the scattering geometry that occur as the stars move with respect to the circumbinary disk. The system reddens as it fades, reversing the trend that was seen during the eclipse epoch. Possible causes for this behavior include variations in the reflectance properties of the disk with distance from the binary and the existence of a putative third source of (red) light. Support from NASA through its Origins of Solar Systems program is gratefully acknowledged. One of (A.B.) was supported by an NSF/REU grant to Wesleyan University in support of the Keck Northeast Astronomy Consortium.

On the Distribution of Large Amplitude Variable Stars in the Orion Nebula Cluster Sara Dwyer¹, W. Herbst²

¹Williams College, ²Wesleyan Univ..

Exhibit Hall

Nine surveys of the Orion Nebula Cluster have been combined into one master catalog. A preliminary analysis of this data set has revealed a number of stars that undergo substantial variations in brightness. While no FU Orionis candidates were found, a number of variables with amplitudes in I between 1 and 3 mag were identified. It is shown that the spatial distribution of these large amplitude variables does not match that of the cluster stars as a whole but exhibits a clear deficiency in the innermost cluster. This suggests that disk accretion, which is thought to drive large amplitude variability in T Tauri stars, is inhibited in the inner ONC. Possible mechanisms for this are proposed, involving the strong UV radiation field and the high density of stars in the core, both of which may affect disk accretion. Support from NASA through its Origins of Solar Systems program is gratefully acknowledged. One of (S. D.) was supported by an NSF/REU grant to Wesleyan University in support of the Keck Northeast Astronomy Consortium.

340.04

Adaptive Optics Imaging of the Spitzer-observed Young Cluster IRAS 20050+2720

Joseph D. Adams¹, M. B. Wilhelm¹, R. A. Gutermuth², S. T. Megeath³, T. L. Herter¹, A. H. Bouchez⁴, R. G. Dekany⁴, J. Roberts⁴, M. Troy⁴, V. Velur⁴

¹Cornell Univ., ²Smith College/Univ. of Massachusetts, ³Univ. of Toledo, ⁴California Institute of Technology.

Exhibit Hall

We have used the Palomar Observatory Adaptive Optics system with a laser guide star and the PHARO instrument to image the Spitzer-observed young cluster IRAS 20050+2720 in the J, H, and Ks bands. Our observations cover a region 99 x 46 arcsec in size at a spatial resolution of 0.1 arcsec, corresponding to 70 AU at the distance of IRAS 20050. None of the 5 Spitzer-identified class I sources in the field showed multiple components at this resolution. However, 37% of the 8 Spitzer-identified class II sources in the field were resolved into binaries ranging in projected separation from 113 AU to 1320 AU. The Ks-band imagery reveals a population of at least 9 low mass objects in the inner 0.05 pc. A protostellar bipolar scattered light nebula with a length of 1600 AU was resolved near the cluster center. We discuss these results and derive the physical properties of the nebula using published protostellar radiative transfer models.

340.05

Searching for Young Stars in Northern Orion

Laurie Urban¹, A. Kraus²

¹Northern Arizona University, ²Institute for Astronomy, University of Hawai'i.

Exhibit Hall

The Orion Molecular Cloud contains many known star-forming regions mostly located in the southern parts of the constellation. However, northern Orion is largely unsurveyed outside of a few well-established clusters meaning there could be more sites of ongoing star formation. We have conducted a search for young stars in northern Orion to find new star-forming regions. Using the MG1 Variable Star Survey we identified 2118 variable stars spanning a region of ~30 deg² from R.A.=4h 00m to 6h 30m and Dec=2.9 to 3.7 degrees. These stars' variability could result from accretion or spots, which are common characteristics of young stars. We use several methods to detect candidate young stars from these data: selection cuts with color-magnitude diagrams (CMDs), measurement of proper motions and visual

inspection of the source images. We make cuts to only include stars that have CMD positions consistent with the Orion sequence, have proper motions within 3 sigma of known Orion members, and are not contaminated by other nearby sources. These cuts identify an area between 5h 20m and 5h 52m in R.A. with a significant overdensity of 74 young star candidates. We will discuss in detail our selection cuts and the implication of these discoveries. This work was conducted by a Research Experience for Undergraduates (REU) position at the University of Hawai'i's Institute for Astronomy and funded by the NSF.

340.06

Thermal Structure of Protoplanetary Disks undergoing Layered Accretion

Michael V. Lesniak¹, S. J. Desch¹

¹Arizona State Univ..

Exhibit Hall

The magnetorotational instability (MRI) is the most likely candidate for angular momentum transport and radial flow of mass in protoplanetary disks (PPDs), but demands a minimum ionization fraction for the gas to couple to the magnetic field. It is known that large regions of PPDs are insufficiently ionized for the MRI to act, and are "dead zones." Only at the disk's surface will the MRI operate: the disk undergoes "layered accretion." The ionization fraction and magnetic coupling are sensitive to the disk's temperature structure. All previous models of PPD temperatures including accretion have assumed a height-independent viscosity. We have constructed the first model of the temperature structure considering accretional heating in the active layers only. Our model self-consistently calculates the temperature and ionization fraction, assuming hydrostatic equilibrium, solving the equations of radiative transfer at each annulus self-consistently with the disk flaring angle, and solving a sophisticated ionization chemistry network. The location of the dead zones and active layers is found using a linear stability criterion accounting for Ohmic dissipation, ambipolar diffusion and Hall terms. As an example, we consider a "typical" T Tauri star (M=0.5 M_{sun}, R=2.5 R_{sun}, T=4000 K) and disk $(M_{DISK}=0.01 M_{Sun}, \text{ column density } \Sigma \alpha r^{-3/2})$. For a magnetic field strength B=0.1 G, we find that inside 1.5 AU the active layers have uniform thickness $\Sigma_a \sim 25$ g cm⁻², but Σ_a rises rapidly with radius between 1.5 and 4 AU until the entire disk is active at larger radii. The midplane temperatures are sensitive to the magnitude and spatial variation of the active layer: they are higher than those of a passive disk, but lower than those of a disk with the same mass accretion rate but a uniform viscosity (no dead zone). Near the boundary of the dead zone, midplane temperatures can actually rise with increasing radius.

340.07

Near-IR Spectral Variability of Young Stars

Stephanie Zajac¹, J. A. Eisner², A. Rudolph¹

¹California State Polytechnic University, ²University of Arizona. Exhibit Hall

Young stars (such as T Tauri and Herbig Ae/Be sources) exhibit photometric variability across the electromagnetic spectrum, including in the visible and infrared regions. Time-variable mass accretion rates may cause some of the observed variability, although other mechanisms such as starspots or structural changes in the circumstellar disks, provide alternative explanations. Spectroscopic observations provide a means to probe accretion via diagnostic emission lines, and to probe the ratio of stellar-to-circumstellar flux via veiling of stellar absorption lines. While spectroscopic variability in the optical range has been previously investigated, variability in the near-IR has not been explored as thoroughly. We have undertaken a project to track the spectral variability of young stars in the near-IR. Using the 90-inch Bok telescope on Kitt Peak, we observed about 40 young stars with FSPEC during two five-night runs separated by one month. As this project continues, in order to extend the timescales

covered by our data, we will survey the same targets under similar circumstances in the summer of 2011. Ultimately, we hope to follow a sample of about 100 young stars with five-night observing runs every month of the year. Here we present initial results showing Brackett gamma Hydrogen line emission for several sources. We show that the emission line luminosity varies, and we use this variability to constrain the mass accretion rate with time for the observed objects. We acknowledge the NSF for funding under Award No. AST-0847170, a PAARE Grant for the Calfornia-Arizona Minority Partnership for Astronomy Research and Education (CAMPARE).

340.08

Searching for Young Stellar Objects in CG4

Chelen H. Johnson¹, L. M. Rebull², V. Hoette³, C. Mallory⁴, K. McCarron⁵, C. Gartner⁶, J. VanDerMolen⁶, L. Gamble⁷, R. Laher², M. Legassie⁸, R. Crump¹, A. Laorr¹, K. Mork¹, E. Steinbergs¹, E. Wigley¹, S. Caruso¹, N. Killingstad¹, T. McCanna¹, L. Matche⁶, A. McCartney⁶, M. Doering⁷, M. Feig⁴, N. Mahmud⁴, T. Selic⁴, S. Kim⁹

¹Breck School, ²SSC/IPAC/CalTech, ³University of Chicago, Yerkes Observatory, ⁴Pierce College, ⁵Oak Park and River Forest High School, ⁶Wisconsin School for the Deaf, ⁷Wisconsin Center for the Blind and Visually Impaired, ⁸SSC/IPAC/CalTech/Raytheon, ⁹University of Arizona.

Exhibit Hall

We used archival Spitzer infrared data to look for new young stellar objects (YSOs) in Cometary Globule 4 (CG4) in Puppis. CG4 is approximately 1300 parsecs away and one of about 30 cometary globules in the Gum Nebula, many of which are known to be forming stars. CG4 is dramatic in appearance, and that has brought it to the attention of both scientists and the public. Our team used archival Spitzer InfraRed Array Camera (IRAC) and Multiband Imaging Photometer for Spitzer (MIPS) data, combined with 2 Micron All Sky Survey (2MASS) data as well as optical data obtained by collaborators. We used infrared excess to investigate the properties of previously known YSOs in this region and identify additional new candidate YSOs in this region. This research was made possible through the NASA/IPAC Teacher Archive Research Project (NITARP) and was funded by NASA Astrophysics Data Program and Archive Outreach funds.

340.09

Submillimeter Array Observations of Embedded Class I Object Barnard 5 IRS1 Erin Brassfield¹, T. L. Bourke²

¹Smithsonian Astrophysical Observatory Submillimeter Array, ²Harvard-Smithsonian Center for Astrophysics.

Exhibit Hall

We present high spatial resolution interferometric observations of the molecular gas and dust surrounding Barnard 5 IRS1, a deeply embedded, low-mass protostellar core in the Perseus star-forming region. Continuum emission at 272 GHz (1.1mm) and molecular lines HCO⁺ J=3-2 and HCN J=3-2 were imaged at spatial resolution of 0.5"-2" (125-500 AU) to investigate Class I YSO disk and envelope structure and dynamics. B5 IRS1 continuum emission appears resolved even on the shortest baselines, and shows a compact, elongated structure perpendicular to the outflow axis. Assuming the emission traces a dusty disk, we estimate a lower limit disk mass of $0.02M_{\odot}$. Paired with singe-dish submillimeter observations, we use our disk mass estimate to calculate an envelope mass estimate of $0.21M_{\odot}$. B5 IRS1 is one of only a few Class I young stellar objects which show emission and a velocity gradient in HCO⁺ J=3-2. If this kinematic pattern is interpreted as a signature of rotation around a central object, then we calculate a mass of $0.1M_{\odot}$ and place this source in the context of recent surveys. Discussion and uncertainties are presented regarding limitations of methods.

An Extended Search for Infrared Variable YSOs

Shaye Storm¹, T. L. Huard¹, L. G. Mundy¹, L. A. Cieza²

¹University of Maryland, ²Institute for Astronomy, Univ. of Hawaii.

Exhibit Hall

There is growing consensus that low-mass star formation is characterized by variable accretion rates. Our analysis of IC 5146 shows that as much as 27% of the young stellar objects (YSOs) exhibited midinfrared variability, with ~10-60% changes in flux density, between two epochs of Spitzer observations separated by 2.5 years. We perform a similar analysis of YSOs in other clouds observed by the Cores-to-Disks and Gould's Belt Spitzer Legacy teams, including selected regions in Perseus and Serpens. By extending this analysis to other regions, we can characterize the magnitude and frequency of midinfrared variability of YSOs in different evolutionary stages and environments. With this increased YSO sample and the broad spectral range offered by the archived Spitzer cryogenic mission, we may better constrain whether such variability is dominated by evolution of the protostellar disk or luminosity changes in the central source, both presumably caused by variable accretion. This analysis is funded by a grant from the NASA Astrophysics Data Analysis program.

340.11

The Pelican Nebula and its Vicinity: a New Look at Stellar Population in the Cloud and around It Richard P. Boyle¹, R. Janusz¹, F. J. Vrba², V. Straizys³, V. Laugalys³, A. Kazlauskas³, J. Stott¹, A. G. D. Philip⁴ ¹Vatican Observatory, ²USNO, ³ITPA, Lithuania, ⁴Union College & ISO. Exhibit Hall

A region of active star formation is located in the complex of dust and molecular clouds known as the Pelican Nebula and the dark cloud L935. In this paper we describe the results of our investigation in the area bounded by the coordinates (2000) RA 20h50m - 20h54m and DEC +44d20m - 44m55d. Our CCD photometry in the Vilnius seven-color system, obtained on the 1.8 m Vatican Advanced Technology Telescope, Mt. Graham, and the 1 m telescope of the USNO Flagstaff Station, is used to classify stars down to V = 17 mag in spectral and luminosity classes. The interstellar extinction values and distances to these stars are determined. Additionally, the data from the 2MASS, MegaCam, IPHAS and Spitzer surveys are analyzed. We present star population maps in the foreground and background of the complex and within it. The known and newly identified YSOs in the area are tabulated.

340.12

Trigonometric Parallaxes to TW Hydrae Association Stars: Analysis and Implications Alysia L. Weinberger¹ G. Anglada Escudé¹ A. Boss¹

Alycia J. Weinberger¹, G. Anglada-Escudé¹, A. Boss¹

¹Carnegie DTM.

Exhibit Hall

Trigonometric parallaxes to claimed members of the TW Hydrae Association were measured using CAPSCam on the duPont Telescope at Las Campanas Observatory. The distances to the fourteen stellar systems, including two pairs of close visual binaries in which the stars are measured independently, complement the six existing parallaxes in the literature. The stars extend from 45 to 110 pc. A moving cluster analysis, in which the three-dimensional velocities of all the stars were propagated back in time from their present location, indicates that there was a time of convergence and shows that the two most distant stars (TWA 14 and 15) are likely not members of TWA. Some particular objects of note are highlighted. 2M1235-39, a proper motion companion to HR 4796, is confirmed to be at the same distance as HR 4796A. The parallactic distance to the TWA 5Aa binary, whose astrometric orbit was measured by Konopacky et al. (2007), is 56 ± 2 pc. This implies a dynamical mass of the two nearly identical M1.5-type stars of 1.4 M_{\odot} , a factor of two higher than inferred using the Mamajek (2005)

convergent-point distance to the system. In addition, good seeing images in 2008, 2009 and 2010 show the brown dwarf companion to TWA 5A.

340.13

Massive Star Formation in the Cygnus-X Region

Dominique Segura-Cox¹, J. L. Hora², H. A. Smith², G. G. Fazio², E. Keto², K. E. Kraemer³, S. Price³, D. Mizuno³, J. D. Adams⁴, L. E. Allen⁵, R. A. Gutermuth⁶, S. Bontemps⁷, S. T. Megeath⁸, N. Schneider⁹, F. Motte⁹, S. Carey¹⁰, R. Simon¹¹

¹University of Michigan, ²Harvard-Smithsonian CfA, ³Air Force Research Laboratory, ⁴Cornell University, ⁵NOAO, ⁶Smith College, ⁷Obs. de Bordeaux, France, ⁸University of Toledo, ⁹CEA-Saclay, France, ¹⁰Spitzer Science Center, ¹¹University of Cologne, Germany.

Exhibit Hall

Massive stars shape galaxy evolution and nearby star formation through feedback mechanisms, yet many aspects of how they form and how they evolve towards the zero-age-main-sequence are still a mystery. The Cygnus-X region contains many massive young stellar objects (YSOs), and at only a distance of 1.7 kpc, this complex is ideal for studying massive star formation. We have observed a list of 25 sources with the IRS, basing our source selection on candidates previously identified in the Cygnus-X Spitzer Legacy Survey using the MIPS and IRAC instruments, the IRAM 1.2 mm survey of the region, and combining these with some older infrared surveys. Common features in the spectra include molecular hydrogen lines tracing shocks at the HII region boundary, polycyclic aromatic hydrocarbon emission in the HII region, and carbon dioxide ice absorption in the envelope. Silicate absorption is also present, allowing us to determine interstellar extinction to the sources. Neon and sulfur forbidden emission lines from ionized gas were also detected. Using the objects' spectral energy distributions, along with line flux ratios derived from the new IRS spectra, we fit models of YSOs to derive stellar mass, age, and temperature, as well as total luminosity of the system, envelope accretion rate of mass onto the stars, and other physical parameters. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 0754568 and by the Smithsonian Institution.

340.14

A Detailed Study of Spitzer-IRAC Emission in Herbig-Haro Objects

Michihiro Takami¹, H. -H Chen¹, J. L. Karr¹, H. -T Lee¹, H. Koh²

¹Institute of Astronomy and Astrophysics, Academia Sinica, Taiwan, ²Astronomy & Space Science Department, Sejong University, Korea, Republic of.

Exhibit Hall

We have made a detailed analysis of Spitzer-IRAC images obtained toward six Herbig-Haro objects (HH 54/211/212, L 1157/1448, BHR 71). Our analysis includes comparisons in morphology between the four IRAC bands (3.6, 4.5, 5.8 and 8.0 μ m) and H₂ 1-0 S(1) at 2.12 μ m; measurements of spectral energy distributions (SEDs) at selected positions; and comparisons of these results with calculations of thermal H₂ emission at LTE (207 lines in four bands) and non-LTE (32-45 lines, depending on the particles used for collisions). We show that, agreeing with some previous studies, the observed shocked emission is attributed to thermal H₂ emission (*T*=1000-4000 K) at non-LTE or LTE, plus CO fundamental emission at 4-5 μ m at high densities. The regions we analyzed do not show clear evidence for another contaminants proposed to date, such as H I, [Fe II], fluorescent H₂ and PAH. The morphologies observed at 3.6 and 4.5 μ m are similar to each other, and to H₂ 1-0 S(1), while the 5.8 and 8.0 μ m emission shows different morphologies from the others in some regions. The latter appear to be more enhanced at the wakes in bow shocks, or less enhanced in patchy structures in the jet. These are explained by different critical densities and excitation temperatures for thermal H₂ emission between four IRAC bands and 1-0 S(1).

We show that the above study is useful for discriminating shocked emission from scattered continuum in outflow cavities, and for investigating interaction between the ejecta of jet flows and ambient gas.

340.15

Narrow-band Monitoring of the UXOR/T Tauri Double Star KK Ophiuchi

Megan Bedell¹, A. Villaume², V. Strelnitski³, G. Walker³

¹Maria Mitchell Obs. & Haverford Coll., ²Maria Mitchell Obs. & U. Mass. Amherst, ³Maria Mitchell Obs.. Exhibit Hall

KK Oph is a double star consisting of an UXOR and its fainter T Tauri companion, separated by 1.6 arcsecs. The goal of this project was to monitor the variability of the combined source in continuum radiation and H α emission. We used two or three narrow-band interference filters centered on 6563 Å (H α) and 6450 Å (adjacent continuum) to measure the intensity of the H α emission separately from that of the continuum. The method of separation is presented along with the results of 3-months monitoring, which included monitoring in the traditional broad-band (BVI) filters. CCD photometry was done with the 24" Ritchey-Chrétien telescope

of the Maria Mitchell Observatory.

Our results indicate that the H α emission of the combined source remains virtually constant or changes only slightly (by less than 20%) while the continuum varies by as much as a factor of 2. There may be some correlation between H α emission and continuum at times of perceptible H α variation. We argue that this continuum variation is primarily due to the UXOR. Our results support similar observations of the UXOR RR Tau (Rodgers et al. 2002; Bedell et al. 2010; Villaume et al, this meeting) and provide evidence that the source of H α emission in UXORs is considerably larger than the source of continuum and that they are widely physically separated, in accordance with the "obscuration model" of UXOR variability (Grinin 1988).

This project was supported by the NSF/REU grant AST-0851892 and the Nantucket Maria Mitchell Association.

340.16

Observing Young Variable Stars Using WFCAM at UKIRT

Thomas Rice¹, C. Aspin², S. J. Wolk¹

¹Harvard-Smithsonian Center for Astrophysics, ²University of Hawaii Institute for Astronomy. Exhibit Hall

We present the results from the analysis of 120 epoch time-series photometry of a 1 square degree region of the Lynds 1003 dark cloud in the Cygnus OB7 association. Using the Wide-Field imaging camera (WFCAM) on UKIRT we were able to obtain almost-nightly J,H,K' photometry over three observing seasons of over 100,000 stars with photometric uncertainty better than 0.02 mag in the range J=10-16 mags and better than 0.5 mag down to J=19.5. From the data we establish criteria for determining variability based on the least-varying sources. We report the discovery of both periodic and stochastic variability for a number of young T Tauri stars. We compare statistical properties of known cluster members with the general field population, and discuss physical models for some of the more interesting sources.

This work was funded by the NSF REU program.

Revealing the Embedded Disk in the Class 0 Protostar L1157-mm

Hsin-Fang Chiang¹, L. W. Looney¹

¹University of Illinois at Urbana-Champaign.

Exhibit Hall

We present new observations of the Class 0 protostar L1157-mm with the Combined Array for Research in Millimeter-wave Astronomy (CARMA). Dust continuum from low (40" or 10,000 AU) to high (0.3" or 75 AU) resolution at both 1.3 mm and 3.2 mm are obtained. While a large-scale flattened structure is seen in molecular lines around L1157-mm, the dust continuum shows circularly symmetric structure at all scales. Also, a compact component is detected with an estimated mass of ~0.01 solar mass, which implies a possible disk component or small-scale envelope structures. To investigate the circumstellar envelope and the embedded disk component, we perform radiative transfer modeling at multiple scales in Fourier space.

340.18

Orbital Parameters for a Pre-Main Sequence Binary System

Nicole Karnath¹, L. Prato², L. Wasserman²

¹Ohio State University, ²Lowell Observatory.

Exhibit Hall

The young system VSB 111 was originally classified as a single-lined spectroscopic binary in the star forming region of NGC 2264. Using the Keck II telescope we measured radial velocities for both the primary and secondary components in the infrared. By combining these data with previous visible light observations of the primary star, we derived the period, eccentricity, and other orbital parameters, as well as the mass ratio of the system. With additional information gained from further observations, for example the inclination derived from the angularly resolved orbit, we will eventually obtain the individual stellar masses, necessary to help to calibrate models of young star evolution. Furthermore, by compiling dozens or even hundreds of mass ratios for young binaries we can use mass ratio distributions to improve our understanding of binary star formation. No infrared excess or any other indication of a circumstellar disk is in evidence for VSB 111, indicating that either the accretion rate has dropped to an undetectable value or that this system has aged enough that its disk has dissipated, if originally present. Given the approximately 900 day period of this system, and its relatively high eccentricity, 0.8, the action of the companion could have been responsible for early dissipation of any disk material.

340.19

The Potential of High Angular Resolution and Contrast FUV Imagery for Studies of Star and Planetary System Formation

C. A. Grady¹, A. Brown², B. Woodgate³, J. Hornbeck⁴, G. Williger⁴, G. Herczeg⁵, J. Brown⁶, S. Brittain⁷, J. Wisniewski⁸, M. Perrin⁹, K. Hamaguchi¹⁰, T. Henning¹¹, I. Kamp¹², R. Petre³, G. Schneider¹³, M. Sitko¹⁴, F. Walter¹⁵, D. Apai⁹, T. Ayres²

¹Eureka Scientific & GSFC, ²University of Colorado, ³NASA's GSFC, ⁴University of Louisville, ⁵MPE, Germany, ⁶CfA, ⁷Clemson University, ⁸U. Washington, ⁹STScl, ¹⁰UMBC & GSFC, ¹¹MPIA-HD, Germany, ¹²Kapteyn Institute, RuG, Netherlands, ¹³Steward Observatory, ¹⁴Space Science Institute, ¹⁵Stony Brook University.

Exhibit Hall

High contrast and high angular resolution imagery has opened new viewpoints on the formation and early evolution of planetary systems, revealing features of protoplanetary and young planetary systems which would go undetected in the integrated measures of the systems. Much of the power of such studies has resulted from pan-chromatic data, but the majority of studies to date have been limited to

optical and longer wavelengths, despite the wealth of atomic, ionic, and molecular tracers of circumstellar material in the FUV. As with high-contrast imaging at longer wavelengths, realizing the full potential of FUV imagery of young stars requires subtraction of PSF template data, which are now available for 3 of the HST ACS/SBC bandpasses. Such imagery has resulted in the first imagery of the circumstellar disk around the Herbig Ae star PDS 144S and can trace the geometry of the molecular gas disk for T Tauri stars. FUV imaging data also provide exquisite detail for molecular outflows for systems like T Tauri, complementing studies in the FIR with Herschel. Such data can also reveal the presence of previously unsuspected disk winds, as seen in GM Aur. Since FUV imagery is sensitive to extinction, FUV data preferentially detect circumstellar material on the near side of disks and the approaching components of outflows, removing ambiguities in disk viewing geometry, and can map, at the highest angular resolution achievable with HST, where disks are shadowed. This is a capability which future UV/Optical telescopes optimized for studies of planetary system formation should not be without. This study is based on data obtained with the Hubble Space Telescope under GO programs 10864, 11336, and 12016.

340.20

Diagnosing The Nature Of H2 Emission In Young Circumstellar Disks

Seth A. Jacobson¹, T. P. Ellsworth-Bowers¹, J. Bally¹

¹University of Colorado at Boulder.

Exhibit Hall

Young circumstellar disks are important for the understanding of the early evolution of stellar systems. While molecular hydrogen has been detected from the regions surrounding many young stellar objects (YSOs), the excitation mechanism for the abundant H2 within the circumstellar disk is unclear [Bary et al., 2003; Bitner et al., 2008]. Three excitation mechanisms have been proposed: shocks within the disk, UV-induced fluorescence at its surface, or X-ray excitation [Beck et al., 2008]. We analyzed H2 emission from the central regions around YSOs to understand the physical processes of and conditions around young circumstellar disks.

Beck et al. [2008] studied a set of bright YSOs in the Taurus-Auriga cloud complex and concluded, on the basis of K-band spectroscopy, that much of the observable H2 emission around these objects was due to shocked gas, likely as part of the associated Herbig-Haro outflows. However, their data lacks the H-band (higher-excitation) H2 lines that can better probe the effects of UV-fluorescence at the surface of circumstellar disks. (UV fluorescence excites the H & K-band transitions, whereas warm (1,800K) shocked gas will have significant flux only in the K-band lines).

We used the TripleSpec instrument (J, H, K-band spectroscopy) on the Apache Point Observatory 3.5-m telescope to detect H2 emission in the inner regions around YSOs in the Taurus-Auriga cloud complex and the Orion Molecular Cloud. TripleSpec is uniquely suited to observing the full suite of ro-vibrational transitions of H2, from which we can extract excitation temperatures and infer (possibly multiple) excitation mechanisms. We have observed all six objects from Beck et al and a larger catalogue at high signal to noise. Our data analysis confirms their conclusions that shock heating is responsible for the bulk of the H2 emission.

We acknowledge the APS department at the University of Colorado for their support.

Mid-Infrared Variability of Orion Protostars using Spitzer

Herwick Hoi Ming Mok¹, S. Terebey¹, J. Stauffer², M. Morales², L. Rebull², P. Plavchan², YSOVAR Team ¹*California State University, Los Angeles,* ²*Caltech.*

Exhibit Hall

We present initial results for Class I protostars in Orion based on synoptic data from the YSO variability (YSOVAR) program. The Spitzer data represent 81 epochs spanning 40 days at 3.6 and 4.5 microns wavelength in the Orion star-forming region. The mid-infrared data are sensitive to the inner regions of disks and thus provide information on inner disk structure and variable accretion rates. The typical magnitude variation is 0.3 mag, small enough to suggest that hot spot plus disk models developed for class II sources may also apply to protostars. However about 10 percent of Orion protostars show variations greater than 0.6 magnitudes. We discuss several models that can produce large magnitude variations in protostars.

340.22

Fundamental Stellar Parameters for Weak-lined T-Tauri Stars in the Rho Ophiuchus and Chamaeleon I & II Star-Forming Regions

Alex Richert¹, D. James¹, J. Bouvier², C. Melo³, N. Santos⁴, A. Aarnio⁵

¹University of Hawaii Hilo, ²Observatoire de Grenoble, France, ³ESO, Chile, ⁴Universidade de Lisboa, Portugal, ⁵University of Michigan.

Exhibit Hall

Using optical photometry and spectroscopy, we have observed X-ray selected, pre-main sequence Weak-lined T-Tauri Stars [WTTS] in the Rho Ophiuchus and Chamaeleon I & II star-forming regions. We exploit these observations in order to determine fundamental stellar characteristics of these WTTSs, such as age and mass. Membership of their parent associations was determined by 1-d radial velocity measurements as well as the significant presence of the age-sensitive, neutral resonance doublet of lithium at 6708A in our high-resolution spectra. Visible and infrared photometric data (in Johnson-Cousins BVIc and 2MASS JHKs filters) were used to obtain four color-dependent estimates of line-ofsight extinction coefficients (Av), which provides evidence of color-excesses due to the presence of any circumstellar disk material.

Spectral types were used to determine stellar temperatures and bolometric corrections, which, along with extinction-corrected V magnitudes, allowed us to calculate four sets of color-dependent bolometric luminosities scaled to the solar value. These data, plotted on HR-diagrams, allow us to determine four independent sets of stellar ages and masses of WTTSs in each star-forming region by comparison of their empirical data to theoretical isochrones and mass-tracks. In the Chamaeleon I & II regions, we find no evidence for a color-dependent age determination of its WTTSs, however in Rho Ophiuchus, we find that isochronal ages are a function of the photometric color used to determine their extinction coefficients.

340.23

Young Star Spectroscopic Binary Mass Ratios Lisa A. \mbox{Prato}^1

¹Lowell Observatory.

Exhibit Hall

Mass is the most fundamental stellar parameter. For a given composition, a star's mass determines the character and duration of its entire life and the manner of its death. Accurate and precise masses comprise the underpinnings of stellar astrophysics, from the mass-luminosity relation, to models of premain sequence evolution. Mass ratio distributions of young stars directly test models of binary star formation. I will describe the progress made over the past decade in using infrared, high-resolution

spectroscopy of young spectroscopic binaries in nearby star forming regions to determine pre-main sequence stellar mass ratios and masses, highlighting the past and ongoing contributions of many student collaborators. This presentation will include the most up to date results for the dynamically determined mass ratio distribution, case studies of the most intriguing young systems, and a preview of a new program to triple the number of precisely known pre-main sequence spectroscopic binary mass ratios.

340.24

Accretion Luminosities of Low Luminosity Taurus YSOs

John Angione¹, S. Terebey¹, L. Rebull², D. Padgett², K. Stapelfeldt³, A. Noriega-Crespo⁴, C. McCabe⁵, Taurus Spitzer Legacy Team

¹CSULA, ²Spitzer Science Center, ³Jet Propulsion Laboratory, ⁴Caltech, ⁵Eureka Scientific. Exhibit Hall

We report the results of follow-up NIR spectroscopy in J, H, and K-bands for low luminosity YSO candidates from the Taurus Spitzer Legacy Survey. YSO candidates with emission lines including H2 and Br Gamma are confirmed as Taurus members. Source properties including Br gamma emission line fluxes are presented for the new low-luminosity members of Taurus. We test the idea that Br Gamma emission is a tracer of accretion in YSOs by comparing the Br Gamma line flux to other measures of accretion luminosity.

340.25

Variability And Disk Geometry In The Classical T Tauri Star Tw Hya Using Mid-infrared Speckle Interferometry

Timothy Arnold¹, J. A. Eisner¹

¹University of Arizona.

Exhibit Hall

We present Gemini T-ReCS mid-infrared speckle interferometry observations at multiple epochs and wavelengths of the classical T Tauri star TW Hya. Our dataset consists of 8.8 and 11.7 μ m observations from 2007 and 11.7 and 18.3 μ m observations from 2009. We resolve the disk emission around TW Hya at all wavelengths, and find significant variability in the distribution of 11.7 μ m emission across the two epochs. We analyze our data in conjunction with previous spatially resolved mid-IR measurements from VLTI and fluxes from the literature in the

 \sim 3-25 μ m range. We construct simple disk models to explain the fluxes and spatial distributions of emission observed for TW Hya, and test the validity of previous models.

This work was supported by the National Science

Foundation through a Graduate Research Fellowship to Timothy J. Arnold.

340.26

Modeling Protoplanetary Disks, with Differnet Initial Conditions, to Test Robustness of Evolved Disk Properties

Amy Jones¹, S. Dodson-Robinson²

¹Texas A&M University, ²University of Texas, Austin.

Exhibit Hall

We have modeled protoplanetary disks with a range of initial properties to determine how each condition effects the general profile of an evolved disk, which is valuable for extracting physical quantities from observations. We varied the mass of the star amongst 0.5, 1.0, and 1.5 solar masses and the initial slope of the surface density between -1.0 and -1.5. Our model consists of 1D and 1+1D codes without the assumption of steady state. We find that the evolved disk's surface density profile does not depend on the initial profile, and is not a power law with a slope of -1.0 or -1.5 (which is usually

assumed). Also, the general shape of the mass accretion rate as a function of radius does not depend on the initial masses. It is clearly not constant, and changes direction (inward to outward flow) around 5 AU to 10 AU, depending on the evolution time. Both of these findings, the surface density profile and mass accretion rates, are critical for future modeling and observations.

340.27

Monitoring H α Emission and Continuum in RR Tauri with Narrowband Filters

Alexa Villaume¹, M. Bedell¹, V. Strelnitski¹, G. Walker¹, J. Williams¹, A. Henden², T. Krajci³ ¹Maria Mitchell Observatory, ²AAVSO, ³Astrokolkhoz Observatory. Exhibit Hall

We present the first results of monitoring of the UXOR RR Tau with narrowband (45-100 Å) interference filters, augmented with the traditional broad-band filters. The applied method allows us to separate the variations of the emission line (H α) and surrounding continuum. For stars as bright as RR Tau, with the equivalent width of H α emission > 10Å, the typical 1 σ error of the extracted emission intensity is <10%. Although the observed light curves do not exclude some correlations between the H α emission and the continuum, the amplitude of the variations in the former is several times smaller. Furthermore, there were periods where continuum changed considerably but the emission line remained constant within the error margin. We conclude that the region responsible for H α emission and the source of continuum in RR Tau are widely separated. Our results are in good agreement with the model proposed by Grinin (1988), where the deep irregular dimming of an UXOR's continuum is due to its occultation by gas/dust cloudlets that are comparable in size to the star but much smaller than the region of H α emission. We also come to the preliminary conclusion that the extracted H α emission light curve may reveal the intrinsic (not connected with the cloud obscuration) variations of the star. This project was supported by the NSF/REU grant AST-0851892 and the Nantucket Maria Mitchell Association.

340.28

A Study of the LkHa233 Group

Abigail Peltier¹, K. N. Allers¹, M. C. Liu² ¹Bucknell University, ²University of Hawai'i. Exhibit Hall

We present the results of a near IR spectroscopic survey of the LkH α 233 group, which are some of the youngest stars in the Lacerta OB association. The sample was selected by choosing stars in the region that had signatures of substantial H α emission. Spectral types were then determined by comparing our spectra to optically classified young TWA stars and field dwarfs. Three of the stars in the sample show large Pa β and Br γ emission lines and the calculated accretion rates for the sample agree with the accretion rates of other young stars of similar masses. The ages of the stars were determined to be around 3-4 Myr. The three stars in our sample have masses ranging from 1.2-1.9 solar masses, compared to only one known low-mass source, which indicates a possible overabundance of intermediate-mass stars. Because there are indications that the stars in this region are products of triggered star formation, it is interesting to learn if the IMF is actually different in this region or if our method of sample selection was biased towards finding intermediate-mass stars. We are currently pursuing a follow up effort to find any low mass members of the group.

340.29

The Discovery of a Photoevaporation-Driven Molecular Outflow from the T Tauri Transitional Disk GM Aur

Jeremy Hornbeck¹, C. A. Grady², A. Brown³, T. Ayres³, D. Apai⁴, S. Brittain⁵, J. M. Brown⁶, K. Hamaguchi⁷, T. Henning⁸, G. Herczeg⁹, I. Kamp¹⁰, M. Perrin⁴, R. Petre¹¹, G. Schneider¹², M. Sitko¹³, F. Walter¹⁴, G. Williger¹⁵, J. Wisniewski¹⁶, B. Woodgate¹¹

¹University of Louisville, ²Eureka Scientific & NASA/GSFC, ³U Colorado, ⁴STScl, ⁵Clemson U, ⁶CfA, ⁷UMBC & NASA/GSFC, ⁸MPIA, Germany, ⁹MPE, Germany, ¹⁰Kapteyn Inst., Netherlands, ¹¹NASA/GSFC, ¹²Steward Obs., ¹³SSI & U. Cincinnati, ¹⁴Stony Brook U., ¹⁵U. Louisville & U. de Nice, ¹⁶U. Washington. Exhibit Hall

Circumstellar disks are not only a byproduct of star formation, but are also the place where planets form and migrate. The dominant gas-phase constituent of disks early in their evolution is H2, and its lifetime in the disk limits the time available for gas giant planet formation and migration. A number of mechanisms have been proposed to remove gas, including photoevaporation in the presence of the stellar X-ray, EUV, and FUV radiation field, but the relative importance of these different components and the point in disk evolution where they become significant remain uncertain. Some models predict enhanced evaporation of gas in the outer disk once the inner portions of the disk have begun to clear. One such system is the T Tauri star GM Aur which hosts a large disk with an r=20 AU central cavity. We have carried out the first high-contrast FUV imaging of this star+disk using HST ACS/SBC and report the detection of the inner 1" (140 AU) of the disk in the FUV and the discovery of a roughly cylindrical structure 90 AU in radius and extending 200 AU orthogonal to the disk, aligned with the previously reported red, polar lobes. The structure is brightest at wavelengths where there are numerous fluorescent molecular hydrogen transitions, both in our imagery and in an archival HST/STIS long-slit spectrum. The cylinder is marginally detected in the ACS/SBC F165LP band indicating that there is some sub-0.2 micron-sized dust entrained in it, but is not detected in ACS/SBC F122M imagery. The radial scale of the footprint of the cylinder on the disk and the absence of atomic emission lines associated with the structure exclude a conventional jet, but are consistent with a photoevaporation-driven outflow. We compare the properties of this outflow with predictions of X-ray, EUV, and FUV-driven disk winds.

340.30

Are X-Rays Produced by V1647 Ori During Optical Outbursts Generated by Accretion?

William K. Teets¹, N. Grosso², K. Hamaguchi³, J. H. Kastner⁴, D. Principe⁴, M. Richmond⁴, D. A. Weintraub¹

¹Vanderbilt University, ²Laboratoire d'Astrophysique de Grenoble, Universite Joseph-Fourier, France, ³Goddard Space Flight Center, ⁴Rochester Institute of Technology. Exhibit Hall

Exhibit Hall

V1647 Ori is a low-mass, deeply-embedded, pre-main sequence star that gained notoriety in 2003 November when it was observed to undergo a strong optical/NIR eruption. V1647 Ori has undergone two optical/NIR outbursts in the last decade, both of which gradually faded over several months to years. These eruptions are thought to be the result of large-scale accretion events.

The X-ray evolution of each of these eruptions has been monitored through multi-epoch Chandra X-ray Observatory observations. We present analysis of five observations that followed the most recent eruption of 2008 August and analysis of the complete suite of CXO observations from 2002 through 2009. We find that V1647 Ori's X-ray flux is well correlated with optical and infrared observations for both epochs, suggesting that the primary X-ray generation mechanism for this star during optical/NIR outbursts is accretion.

Light curves of the recent observations (2008 September 18 - 2009 April 21) show V1647 Ori's X-ray flux was variable on short timescales. The pattern of X-ray median photon energy, mean count rate, and mean hardness ratio of these short-duration (few ks) events is very similar to those of the long-term (few months to years) variations, suggesting that the short-duration variability is also accretion-related. The spectra are very well modeled with a single-temperature plasma subject to intervening hydrogen column density. With the hydrogen column density, plasma temperature, and chemical abundance freely varying, the models for the recent spectra converged to fits with a plasma temperature of 4-6

keV, a column density of $4-5 \times 10^{22}$ cm⁻², and a chemical abundance of about 0.8 solar. During the 2008-2009 epoch, the X-ray luminosity varied from a peak of 8 x 10^{30} ergs/s to a minimum of about 2 x 10^{30} ergs/s. This work was funded by a grant from NASA's Chandra X-ray Center.

340.31

Star Formation In DC274.2-0.4: Exciting Or Not?

Tracy L. Huard¹, M. M. Dunham², T. L. Bourke³, P. C. Myers³, J. K. Jørgensen⁴, D. C. Murphy⁵, R. J. Williams⁵, D. D. Kelson⁵, N. J. Evans II⁶, B. A. Whitney⁷, D. J. Wilner³

¹Univ. of Maryland, ²Yale University, ³Smithsonian Astrophysical Observatory, ⁴University of Copenhagen, Denmark, ⁵Carnegie Observatories, ⁶University of Texas at Austin, ⁷Space Science Institute. Exhibit Hall

Mid-infrared observations, obtained by the Cores-to-Disks Spitzer Legacy team, revealed several protostars and young stellar objects in the core DC274.2-0.4. With evidence for a nearby distance (130-200 pc), one of these sources qualifies as a Very Low Luminosity Object (VeLLO) and appears to be among the lowest luminosity embedded sources known, with an internal luminosity of 0.01-0.03 Lsun. If this source is indeed a VeLLO, then its discovery is exciting as it may represent the earliest stage protostar or proto-brown dwarf yet detected. However, the internal luminosity critically depends on the distance and some evidence suggests that DC274.2-0.4 is more distant (>400 pc), making this core a more typical site of low-mass star formation. We review the different distance determinations, and present new optical spectra obtained with Magellan/IMACS to help settle the ambiguity. Finally, we discuss the star-forming environment of DC274.2-0.4 in light of additional infrared observations from CTIO/ISPI, Magellan/MMIRS, and HST/WFC3.

340.32

A NIR Spectroscopic Study of Potential Mid-IR Variability Mechanisms for Young Stars

Christopher Faesi¹, K. R. Covey², R. Gutermuth³, P. Plavchan⁴, J. Stauffer⁴, L. Rebull⁴, M. Morales-Calderon⁴

¹Indiana University, ²Cornell University, ³Smith College, ⁴Spitzer Science Center. Exhibit Hall

Recent studies have uncovered numerous examples of mid-infrared (mid-IR) variability in young stellar objects (YSOs). There are several possible physical mechanisms that may be responsible for these variations. We have obtained and analyzed multi-epoch near-infrared (NIR) spectra for five YSOs in ρ-Ophiuchus with contemporaneous mid-IR light curves obtained as part of the YSOVAR Spitzer/IRAC survey. These targets were chosen due to their history of active mass accretion: our spectral measurements demonstrate the time dependence of these YSOs mass accretion rate through measurements of the strength of their Brγ and Paβ emission over 10 epochs. While we find that this rate is variable over timescales of days to weeks, we do not see a correlation

between their mid-IR light curves and any of the following parameters: (1) mass accretion rate, (2) changes in K-band veiling, or (3) variability in extinction along the line of sight. We conclude that the physical processes driving these variations arise in a region of the circumstellar disk that is not directly affected by ongoing mass accretion. We also look for correlations between mass accretion rate and the strength of the components of the He λ 10830 line. The strength of the blueshifted absorption, which is thought to be an indication of accretion-induced stellar winds, does not appear to correlate with the accretion rate. However, the redshifted emission, where present in our spectra, does show both quantitative and qualitative similarities with the accretion-sensitive HI lines, including commensurate variability, and thus could potentially be used as another spectral signature for mass accretion in young stars.

Characterizing the CO A-X Emission in Young Circumstellar Disks

Eric Schindhelm¹, K. France¹, G. Harper², H. Yang¹, A. Brown¹

¹Univ. of Colorado, ²Trinity College Dublin, United Kingdom.

Exhibit Hall

We present broad CO emission features in HST-COS FUV spectra of 6 classical T Tauri stars. The CO A-X fluorescence is modeled as photo-excitation by stellar C I emission, with a possible pumping contribution from chromospheric far-UV accretion present in young circumstellar disks. We focus on the 1600 (v'=0,v''=1), 1660 (v'=0,v''=2), and 1713 (v'=0,v''=3) Angstrom CO bands, as emission at shorter wavelengths experiences strong self-absorption and spectral confusion with photo-excited H2. Although the individual ro-vibrational lines are not resolved, the blended bands vary enough with temperature and column density to form confidence intervals from chi-squared fits to the data. The range in ages of our targets can allow us to characterize CO abundances vs. H2 abundances and age in proto-planetary disks.

340.34

FUV Spectroscopy Of Outflows And Disks Around The Intermediate Mass Pre-main-sequence Stars HD135344B And HD104237

Alexander Brown¹, G. Herczeg², J. M. Brown³, F. M. Walter⁴, T. R. Ayres¹, DAOof TAU Team ¹Univ. of Colorado, ²MPE, Germany, ³CfA, ⁴SUNY.

Exhibit Hall

The intermediate-mass, pre-main-sequence (Herbig Ae/Fe) stars HD135344B (F4) and HD104237 (A8 IV-V) are both still surrounded by almost face-on circumstellar disks. The disk around HD135344B is a

"transitional" disk with a 25 AU radius cleared inner hole but still with some gas and dust very close to the star. We have obtained FUV spectra of these stars using the HST COS and STIS spectrographs that show that both stars have dramatic high-velocity (terminal velocity = 300-400 km/s) outflows and rich fluorescently-excited molecular hydrogen emission, originating primarily from warm gas in their disks. We present these FUV spectra and outline the outflow and disk properties implied by the observed emission and absorption line profiles. The profiles and widths of the molecular hydrogen lines provide strong constraints on the location of the emitting regions.

This work is supported by HST grants for GO projects 11828 and 11616, and Chandra grant GO9-0015X to the University of Colorado.

340.35

The Mass Evolution Of Envelopes & Disks During The Embedded Protostellar Stage

Tyler L. Bourke¹, J. Jorgensen², R. Visser³, E. van Dishoeck³, D. Wilner¹, D. Lommen³, M. Hogerheijde³, P. Myers¹

¹Harvard-Smithsonian, CfA, ²University of Copenhagen, Denmark, ³Leiden University, Netherlands. Exhibit Hall

A key question in protostellar evolution is how is matter accreted from the large-scale envelope thought the circumstellar disk and onto the

central protostar. Observations that measure the mass of these components are needed to provide constraints on models of mass evolution and disk growth in the earlier (embedded) phase of protostellar evolution. Previously we presented a study of a sample of 20 low-mass Class 0 and I protostars in Taurus and Ophuichus using the Submillimeter Array (SMA) and single-dish bolometer observations, with which the envelope and disk masses, and in some cases the protostellar mass, could be measured. We found that both Class 0 and I protostars are surrounded by disks with typical masses of about 0.05 solar masses, with large scatter, suggesting no correlation between disk mass and

evolutionary stage. However, envelope masses decrease rather abruptly from 1 solar mass in the Class 0 phase to 0.1 solar mass in the Class I phase. Typically in the Class 0 phase envelopes contain 10 times or more mass than disks, but only 2-4 times the disk mass during the Class I phase. These results suggest that disks are formed early in protostellar evolution and that matter is accreted and dispersed rapidly from the envelope. Here we present the results of an expanded study, including a significant increase in the number of sources and regions observed with the SMA.

This work is supported by NASA Origins grant NXX09AB89G.

341

White Dwarfs Poster Session *Exhibit Hall*

341.01

Multi-survey and LDA Techniques for Cool White Dwarf Discovery

Conor C. Sayers¹, J. P. Subasavage², P. Bergeron³, J. R. A. Davenport¹, Y. AlSayyad¹ ¹University of Washington, ²Cerro Tolo Inter-American Observatory, Chile, ³Universiten de Montrenal, Canada.

Exhibit Hall

We search for new white dwarfs by compiling data from multiple surveys including the Sloan Digital Sky Survey (SDSS), the Two Micron All Sky Survey (2MASS), the Lepine & Shara Proper Motion North (LSPM-North) catalog, and USNO-B catalog. By initially filtering via reduced proper motion diagrams, color cuts, and atmospheric model adherence, white dwarf candidates are isolated for followup spectroscopy. Subdwarf contaminates were observed to persist through the initial filtering process solely in the modeled T_{eff} regime < 7000 K. To mitigate this contamination effect, linear discriminant analysis (LDA) was utilized in further cool white dwarf candidate searches. We present spectroscopy of 17 white dwarfs taken with the CTIO 4m and the APO 3.5m telescopes, while 30 additional white dwarf spectra were found in the SDSS database. These spectra represent a range of spectral types and T_{eff} and serve to investigate the merit of LDA as a tool for contaminant identification and elimination. Our LDA process aided in the discovery of two cool white dwarfs with preliminary distance estimates of 13.6 pc and 15.7 pc.

This research was supported by the 2010 CTIO REU program. Based on observations obtained with the Apache Point Observatory 3.5-meter telescope, which is owned and operated by the Astrophysical Research Consortium.

341.02

The Local White Dwarf Population: The 25 pc Sample

Jay B. Holberg¹, E. M. Sion², T. D. Oswalt³

¹Univ. of Arizona, ²Villanova University, ³Florida Institute of Technology. Exhibit Hall

Currently the most complete sample of white dwarf stars comes from the local white dwarf population within 20 pc, which is believed to be 80 percent complete. This sample contains some 132 degenerate stars. We hope to effectively double the number of known local white dwarfs by extending the sample boundary to 25 pc, while still maintaining a high level of completeness. We discuss plans for extending the local sample and some of the studies that will be possible with this enlarged population. This work was funded in part by NSF Grant AST-1008845.

Testing the Initial-Final Mass Relation of White Dwarf Stars using Wide Binaries Terry D. Oswalt¹, J. Zhao¹, J. Holberg²

¹Florida Institute of Technology, ²University of Arizona.

Exhibit Hall

We present an initial-final mass relation for white dwarf stars in wide binaries that have a main sequence companion. The effective temperatures and gravities of each white dwarf component are measured by fitting theoretical model spectra to observed spectra. From these, cooling times and masses are obtained using theoretical cooling tracks. The total age of each binary is estimated from the chromospheric activity of its main sequence component. The difference between the total age of the binary and its white dwarf cooling time is approximately the main sequence lifetime of the white dwarf. From this the initial mass of the WD can be computed from standard main sequence evolution models. Since our wide binaries are much older than nearby clusters, the initial masses of our white dwarfs tend to sample the low mass end of the initial-final mass relation, a regime where clusters provide sparse information. Our results also suggest the metallicity of a star does not affect the amount of post main sequence mass loss that occurs, at least for low mass progenitors.

341.04

Testing Stellar Evolution Theory with the Binary Fraction of Low-Mass White Dwarfs Justin Brown¹, M. Kilic², W. Brown²

¹Franklin and Marshall College, ²Smithsonian Astrophysical Observatory. Exhibit Hall

We describe spectroscopic observations of 21 low-mass (&It; 0.45 Msolar) white dwarfs from the Palomar-Green Survey obtained over a period of three years. We use both radial velocity analysis and infrared photometry to identify binary systems, and find that the fraction of single, low-mass white dwarfs is 30% with an uncertainty of 18%. We discuss the inverse relationship between the mass and the binary fraction of white dwarfs and compare this relationship to existing theoretical models. We also compare the period distribution of 0.2 and 0.4 solar mass white dwarfs and find that lower mass white dwarfs have systematically shorter orbital periods. Our results support the idea that single low-mass white dwarfs can be formed through enhanced mass-loss from a metal-rich progenitor star. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 0754568 and by the Smithsonian Institution.

341.05

EC14012-1446 and WDJ1524-0030: Decoding Convection with White Dwarf Lightcurves

Judith L. Provencal¹, M. Montgomery², S. Mulally³, J. Dalessio¹, H. Shipman¹, Whole Earth Telescope ¹University Of Delaware, ²University Of Texas, ³Kepler Science Office. Exhibit Hall

Convection remains one of the largest sources of theoretical uncertainty in our understanding of stellar physics, with implications ranging modeling the cores and envelopes of stars, planetary atmospheres, and accretion disks, to predicting the pulsation frequencies of solar-like stars. The WET is conducting a long term project to empirically determine the physical properties of convection in the atmospheres of pulsating white dwarfs. The technique, outlined by Montgomery et al. (2010), uses information from nonlinear (non-sinusoidal) pulse shapes of the target star to empirically probe the physical properties of its convection zone. EC14012-1446 and WDJ1524-0030 were chosen as candidates for this technique based on the characteristics of their light curves. We present results from WET runs in 2008 (EC14012-1446), and survey the remarkable behavior of WDJ1524-003 over from WET runs in 2009 and 2010.

R Coronae Borealis Stars formed from Double White Dwarf Mergers

Jan E. Staff¹, F. Herwig², A. Menon², W. Even³, J. Tohline¹, G. Clayton¹, P. Motl⁴, C. Fryer³, T. Geballe⁵ ¹Louisiana State University, ²University of Victoria, Canada, ³Los Alamos National Laboratory, ⁴Indiana University Kokomo, ⁵Gemini Observatory.

Exhibit Hall

R Coronae Borealis (RCB) stars are hydrogen-deficient variable stars that suddenly fade by several magnitudes at irregular intervals whereafter they gradually return to their original brightness over a period of some months. The origin of RCBs remain a mystery. It is often thought that they are the result of the merger of a He and a CO white dwarf, while the fading is thought to be due to the formation of dust blocking light from the star. We are working on revealing the secrets behind the origin of RCBs. Here we present the results of 3 dimensional hydrodynamic simulations of the merger of a double white dwarf system where total mass is 0.9 M_{\odot} and initial mass ratio is q=0.7. We use a zero-temperature plus ideal gas equation of state that allows for heating through shocks. These simulations allow us to follow the evolution of the system for 10-20 initial orbital periods (1000-2000 seconds), from the onset of mass-transfer to a point after merger when the combined object has settled into a nearly axisymmetric, rotationally flattened configuration. The final merged object from the hydrodynamics simulation is then used as input for a stellar evolution code where the object's evolution can be followed over a much longer (thermal and/or nuclear) timescale. A preliminary post-merger stellar evolution simulation shows how an initial configuration of a 0.7 CO WD surrounded by 0.3 M_{\odot} of dynamically accreted He evolves on a time scale of 10^5 years to the location of the RCB stars in the H-R diagram at an effective temperature T_{eff} <7000 K and log L~4.

We acknowledge support from NASA Astrophysics Theory Program grant number NNX10AC72G.

341.07

A Comparison of Stellar Mass-Transfer & Merger Simulations

Joel E. Tohline¹, P. Motl², S. Diehl¹, W. Even³, G. Clayton¹, C. Fryer³ ¹Louisiana State Univ., ²Indiana University, Kokomo, ³LANL. Exhibit Hall

We present detailed comparisons of 3D stellar mass-transfer and merger simulations that have been carried out using two very different numerical hydrodynamic algorithms -- a finite-volume "grid" code (typically using 4M cylindrical grid cells) and a smoothed-particle hydrodynamics (SPH) code (typically using 1M particles). In all cases the initial binary models contain synchronously rotating, n = 3/2 polytropic stars of a specified mass ratio (q = $M_{donor}/M_{accretor}$) that are in circular orbit with one star (the donor) marginally filling its Roche lobe. In our "base" set of 8 comparison simulations, we have followed the evolution of binaries having four different initial mass ratios (q₀ = 1.3, 0.7, 0.5, 0.4) and each is evolved using two different equations of state: polytropic (P) and ideal-gas (I). In addition, some evolutions are repeated using a different numerical resolution and/or a different initial episode of "driving" to initiate mass-transfer. In the case of the binary systems with q₀ = 1.3 and q₀ = 0.7, the codes show a remarkable level of quantitative agreement; in the former case, the two stars merge and, in the latter case, the donor gets tidally disrupted. Binary systems with q₀ = 0.5 or 0.4 enter a long phase (> 10-20 orbits) of stable mass-transfer during which the binary separation steadily increases; tidal disruption of the donor may ultimately occur if sufficiently deep contact is made between the Roche lobe and the donor during an initial episode of "driving."

This work has been supported by grants AST-0708551 and DGE-0504507 from the U.S. National Science Foundation; by grants NNX07AG84G and NNX10AC72G from NASA's ATP program; and by grants of high-performance computing time on the TeraGrid, at LSU and across LONI (Louisiana Optical Network Initiative).

Including the Effects of Hydrogen Burning in the Evolution of Compact Double-Degenerate Binaries David L.A. Kaplan¹, L. Bildsten², J. Steinfadt²

¹University of Wisconsin, Milwaukee, ²University of California, Santa Barbara. Exhibit Hall

Very low mass (<0.2 Msun) He white dwarfs can have a layer of stable hydrogen burning near the surface, and this layer can dramatically alter the structure of such a white dwarf. In the last year, a number of new binary systems containing such objects in short (<12 hr) orbits with more massive white dwarfs have been discovered. Making use of recent calculations of the internal structures of low-mass white dwarfs, we present evolutionary calculations exploring the effects of these white dwarfs on the mass-transfer history of compact double-degenerate binaries. We show that mass transfer starts at a low level when the two white dwarfs are farther apart than would otherwise be found and that the accreted material can burn stably, but that the evolution of the He white dwarf causes the orbital period to initially decrease. Following a period minimum the system grows wider, but that eventual outcome can depend on the masses and temperatures of the component stars.

341.09

White Dwarf Collisions as Potential SNIa Progenitors

Wendy Hawley¹, T. Athanassiadou¹, C. Raskin¹, M. Richardson¹, E. Scannapieco¹, F. Timmes¹ ¹*Arizona State University*.

Exhibit Hall

We present zero impact parameter 3D collisions of white dwarfs using the Eulerian grid code FLASH to explore the possibility of such events being part of the overall Type Ia Supernovae (SNIa) population. The models span collisions of equal and unequal mass carbon-oxygen white dwarfs between 0.5 and 0.9 solar masses. We find the mass of Ni-56 produced ranges from 0.0 to 0.9 solar masses depending on the white dwarf mass pairings. This is sufficient Ni-56 production to span the subluminous to overluminous range of SNIa. We compare these results to a parallel study carried out using a Lagrangian particle code SNSPH. We find the FLASH calculations produce less Ni-56 than the SNSPH models, which we attribute to differences in ignition criteria.

342 *Variable Stars* Poster Session *Exhibit Hall*

342.01

The 3.6 Year DIRBE Near-Infrared Light Curve Archive

Kathleen E. Kraemer¹, S. D. Price¹, B. J. Smith², T. A. Kuchar³, D. R. Mizuno³ ¹Air Force Research Lab, ²East Tennessee State University, ³Boston College. Exhibit Hall

After the 10-month supply of cryogens ran out on the Diffuse Infrared Background Experiment (DIRBE), the four shortest wavelength channels, 1.25, 2.2, 3.5, and 4.9 microns, continued to obtain data for an additional ~2.7 years. Out of the 11,000+ sources in the DIRBE Point Source Catalog (DPSC; Smith et al. 2004) from the cryogenic phase of the mission, we selected a quarter (~2700) whose photometric and spatial characteristics indicated they would likely have good near-IR data during the post-cryo phase. We have reprocessed and recalibrated the weekly-averaged post-cryo data to place them on the same basis as the cryo data, albeit at a slower cadence. The resultant 3.6 year light curves have been analyzed for variability using the Lomb-Scargle periodogram formulation. With the periodograms, we have (1) found that 97% of the mid-IR standards in the Air Force Calibration Star Network are also non-variable in the

near-IR; (2) confirmed that 93% of the stars flagged as variable in the DPSC are variables or candidate variables; and (3) found an additional 324 variables and candidates which were not so flagged in the DPSC. Additionally, we have begun to investigate wavelength-dependent phase lags between the visible and the near-IR maxima, extending study of Smith et al. (2006) to those stars with periods longer than the ~300 day cryo mission. The light curve data are available to the community through the Vizier service at the Centre de Donnees Astronomique de Strasbourg.

342.02

OGLE II Eclipsing Binaries In The LMC: Analysis With Class

Edward J. Devinney¹, A. Prsa¹, E. F. Guinan¹, M. DeGeorge¹

¹Villanova University.

Exhibit Hall

The Eclipsing Binaries (EBs) via Artificial Intelligence (EBAI) Project is applying machine learning techniques to elucidate the nature of EBs. Previously, Prsa, et al. applied artificial neural networks (ANNs) trained on physically-realistic Wilson-Devinney models to solve the light curves of the 1882 detached EBs in the LMC discovered by the OGLE II Project (Wyrzykowski, et al.) fully automatically, bypassing the need for manually-derived starting solutions. A curious result is the non-monotonic distribution of the temperature ratio parameter T2/T1, featuring a subsidiary peak noted previously by Mazeh, et al. in an independent analysis using the EBOP EB solution code (Tamuz, et al.). To explore this and to gain a fuller understanding of the multivariate EBAI LMC observational plus solutions data, we have employed automatic clustering and advanced visualization (CAV) techniques.

Clustering the OGLE II data aggregates objects that are similar with respect to many parameter dimensions. Measures of similarity for example, could include the multidimensional Euclidean Distance between data objects, although other measures may be appropriate. Applying clustering, we find good evidence that the T2/T1 subsidiary peak is due to evolved binaries, in support of Mazeh et al.'s speculation. Further, clustering suggests that the LMC detached EBs occupying the main sequence region belong to two distinct classes. Also identified as a separate cluster in the multivariate data are stars having a Period-I band relation. Derekas et al. had previously found a Period-K band relation for LMC EBs discovered by the MACHO Project (Alcock, et al.). We suggest such CAV techniques will prove increasingly useful for understanding the large, multivariate datasets increasingly being produced in astronomy.

We are grateful for the support of this research from NSF/RUI Grant AST-05-75042 f.

342.03

Spitzer Observations of Stellar Variability in the Mid-Infrared

Richard DeCoster¹, P. Piper², B. Thomas³, A. Antonow¹, A. Sehgal¹, R. Rosignolo², J. Romero², O. Rudio³, D. Brennan³, D. W. Hoard⁴, S. Howell⁵

¹Niles West High School, ²Lincoln-Way North High School, ³North Middle School, ⁴Spitzer Science Center, California Institute of Technology, ⁵NOAO.

Exhibit Hall

We used archival mid-infrared data from the Spitzer Space Telescope to search three Infrared Array Camera (IRAC) fields containing exoplanet host stars (Tres-2, Hat-P-1b, and Tres-4) for additional stars that vary in the mid-infrared. We used the Image Reduction and Analysis Facility (IRAF) software to determine photometry for all field stars detected by 2MASS, plus a number of manually selected stars in each field that were not contained in the 2MASS Point Source Catalog. In total, 242 stars in 6447 images were surveyed (62 stars in 1073 4.5-micron images of the Tres-2 field spanning 3.5 hr, 49 stars in 1605 3.6-micron and 4.5-micron images of the Hat-P-1b field spanning 6.0 hr, and 131 stars in 2164 4.5-micron images of the Tres-4 field spanning 8.0 hr). We created light curves for each of the stars and

visually inspected these light curves for variability above the level of the noise. We found one star in the Tres-4 field that displayed periodic variability (P = 0.082 days) when phase-folded. We noted that this star was not listed in the 2MASS catalogue. Thus, we found that approximately 0.4% of stars observed in the mid-infrared, down to our sensitivity level (approximately 0.15 mJy at 4.5 microns for a S/N = 5 detection), exhibit variability. This research was conducted within the NASA/IPAC Teacher Archive Research Project (NITARP).

342.04

Multiphase Comparison of PL/PC Relations

Earl Bellinger¹, S. Kanbur¹, C. Ngeow²

¹SUNY Oswego, ²National Central University, Taiwan. Exhibit Hall

The Cepheid PL relation is of paramount importance in astrophysics in establishing a distance scale that can be used to estimate Hubble's constant to better than 1% accuracy.

Here we present convincing evidence that the Cepheid PL relation in the LMC and SMC is a highly dynamic quantity which varies significantly when considered as a function of phase. We also present a detailed metallicity comparison of the mulitphase PL relations in the LMC and SMC.

342.05

Nonradial Pulsation Periods of B and Be Stars in NGC 3766

Rachael M. Roettenbacher¹, M. V. McSwain¹

¹Lehigh University.

Exhibit Hall

Nonradial pulsations (NRPs) are spherical harmonic waves that propagate across the stellar surface and are driven beneath the surface by an ionized iron opacity mechanism. NRPs are a possible formation mechanism of the equatorial disk surrounding a Be star. Be stars are non-supergiant B-type stars that have been observed at some point with emission in the Balmer or other spectral lines. The emission features are the result of an equatorial mass-loss disk. Transient Be stars are those that have been observed with both emission features due to a circumstellar disk and with a non-emitting B-type spectrum. We observed NGC 3766, a young open cluster rich with B and transient Be stars, for 25 nights over three years at the CTIO 0.9m telescope using the Strömgren *uvby* filter system. We present the results of a period search to investigate presence of nonradial pulsations in the B and Be cluster members.

We acknowledge support from Lehigh University and the Harriet G. Jenkins Pre-Doctoral Fellowship Program, supported by NASA and UNCF.

342.06

The Strange Case of Hubble's V19 in M33: Monitoring the Remarkable Changes and Possible Real-Time Evolution of a Classical Cepheid

Scott G. Engle¹, E. Guinan¹, L. Macri², A. Pellerin²

¹Villanova University, ²Texas A&M.

Exhibit Hall

In the influential work "A Spiral Nebula as a Stellar System: Messier 33" (Hubble 1926) Edwin Hubble determined the distance to M33 by using 35 Cepheids he discovered. One of those Cepheids was designated V19. Observations revealed V19 to have a 54.7-day period and B-band (converted from photographic magnitudes) light amplitude of 1.1-mag. Its mean B-magnitude was 19.59+/-0.23. Its properties were consistent with the Period-Luminosity Law for M33 derived by Hubble at that time. Follow up observations in 1996-1997 as part of the DIRECT Program (Macri et al. 2001), however, revealed large and surprising changes in the properties of V19. Its mean B-magnitude had risen to

19.05+/-0.05 and its amplitude had fallen to < 0.1-mag. The DIRECT study thoroughly checked for possible misclassifications of the variable or contamination by nearby objects, and found none. For all intents and purposes, V19 was no longer a Classical Cepheid, or at least varying below the detectable levels of the photometry. The only other well-documented instance of Cepheid pulsations declining over time is in the case of Polaris - whose V-band amplitude fell from just over 0.1-mag to below 0.03-mag over the course of a century (Engle et al 2004). Also, a study of Polaris' visual magnitudes over the past two millennia has shown a possible increase in brightness of 1-mag over the past 1000 years. The changes present in V19 are obviously on a much more dramatic scale.

We report on our continuing efforts to monitor the behavior and properties of Hubble's V19 in M33. Photometry has been carried out with the WIYN 3.5-m telescope and the 1.3-m RCT (Robotically Controlled Telescope) at KPNO. It is our hope that these observations will help solve the mystery of V19 and its unprecedented evolutionary behavior.

We gratefully acknowledge NASA/HST grant and NSF/RUI grant AST1009903.

342.07

An Optical Flare Rate Census of Galactic Bulge Dwarf Stars

Adam Kowalski¹, R. A. Osten², K. C. Sahu², S. L. Hawley¹

¹University of Washington, ²Space Telescope Science Institute.

Exhibit Hall

Flare emission is thought to be the observational consequence of transiently heated plasma by the dynamic interaction of magnetic fields throughout the stellar atmosphere. Other magnetic activity measures indicate that age may be a fundamental parameter for the generation and presence of surface magnetic fields. However, flares have been observed on both old and young stars, and the importance of age on the flare rate of a stellar population is not well known, as previous flare rate studies have been limited to the surrounding solar neighborhood and young disk population. The SWEEPS project monitored a 202x202 arcsec dense stellar field in the Sagittarius window of the Galactic bulge for a continuous seven-day period using the HST/ACS F606W (V) and F814W (I) filters. These data were aimed at a search for transiting exoplanets, but the high-cadence light curves, consisting of ~260 epochs in each filter, provide a unique repository to mine for flare incidence in an evolved stellar population of dwarfs. We employ a customized algorithm to search for flares on ~200,000 cool dwarfs of intermediate-old age, and we study the stellar flare rate and flare properties as a function of mass, V - I color, and the degree of underlying variability. These rates allow us to compare to the flare rates of younger stars and to extend the investigation of the evolution of magnetic activity to an older stellar population.

342.08

Starspots on LO Pegasi, May-July 2010

Robert O. Harmon¹, R. Robinson², A. Roy¹

¹Ohio Wesleyan University, ²Michigan State University.

Exhibit Hall

We present surface maps of LO Pegasi based on BVRI light curves obtained during May-July 2010 via differential aperture photometry performed on CCD images acquired at Perkins Observatory. The light curves were processed through a light-curve inversion algorithm which makes no a priori assumptions regarding the number of starspots or their shapes. In addition to mapping the surface, we found that the rotational period during this interval was P = 10.153 h, which differs by 1.7% from the nominal value P = 10.17 ± 0.8 h found by Lister et al. 1999, MNRAS, 307, 685. We speculate that this may represent an effect of differential rotation of the stellar surface layers.

This work was supported by the NSF REU Program and the Ohio Wesleyan University Summer Science Research Program.

342.09

BVRI Photometry of XX Cygni

Michelle Spencer¹, M. D. Joner¹, J. L. Bugno¹, L. A. Joner¹

¹Brigham Young University.

Exhibit Hall

We present new BVRI light curves for the SX Phoenicis star XX Cygni. These data were secured at the Brigham Young University West Mountain Observatory during the summer of 2010 using both the 0.31-meter and 0.51-meter telescopes equipped with CCD detectors and filters matched to the BVRI Johnson-Cousins system. The light curves exhibit no anomalies or indications of a secondary pulsation mode. We have combined our observed times of maximum light with unpublished observations and archival data to examine the nature of reported period variations.

We thank the College of Physical and Mathematical Sciences for continued support of mentored undergraduate research projects. We also acknowledge continued support from the Brigham Young University Department of Physics and Astronomy for operational funding and research support at the West Mountain Observatory.

342.10

The Study of Variability in Four Oxygen-Rich Proto-Planetary Nebulae

Kristie Shaw¹, B. J. Hrivnak¹, W. Lu¹

¹Valparaiso University.

Exhibit Hall

In this project, we observed and analyzed the light and color variations of four proto-planetary nebulae (PPNe), IRAS 17436+5003, 18095+2704, 19386+0155, and 19475+3119. PPNe are a late stage in a star's evolution, after the asymptotic giant branch, when the star is in the process of losing its outer layers and exposing its core. Observations were carried out at the Valparaiso University Observatory, using the 0.4-meter telescope and CCD camera. This is a long-term study, incorporating 14 to 17 years of observations of these objects. Other data, published and from sky surveys, were combined in this comprehensive study. They each show a cyclical variation in brightness with variable amplitude, and they are each redder (cooler) when fainter. The derived periods are ~47, 114, 101, and ~39 days for IRAS 17436+5003, 18095+2704, 19386+0155, and 19475+3119, respectively. The bright source IRAS 17436+5003 (HD 161796) has a rich observation history and shows periods that range from 43 to 62 days. We acknowledge support for this research from the NSF and from the Indiana Space Grant Consortium.

342.11

Light Curve Analysis Of Tt Oph And Uz Oph

Jennifer Cash¹, B. Pugh¹, E. Maina¹

¹South Carolina State Univ..

Exhibit Hall

TT Oph and UZ Oph are both classified in the GCVS as RV Tauri stars, pulsating variables with alternating deep and shallow minima. The literature indicates that the RV Tauri nature of these two stars is questionable. We have examined the AAVSO light curves of these objects for the eight year period of 2002-2010. We will present our analysis of the light curves and discuss how their recent behavior compares with past behavior as presented in the literature.

Support for this work was provided by the NSF PAARE program to South Carolina State University under award AST-0750814.

Spectral Variations of Three RV Tauri Stars

Donald K. Walter¹, C. Kurgatt¹, S. Howell², J. Cash¹

¹South Carolina State Univ., ²National Optical Astronomy Observatory.

Exhibit Hall

UZ Oph, TT Oph and AD Aql are classified as RV Tauri stars in the General Catalog of Variable Stars. We present preliminary results of our study of the spectral variations of these stars including observations from 2003 to the present. Changes on the order of several spectral types and luminosity classes are observed. We discuss each object's shift in position on the L vs. T diagram as a function of the phase of their light curve. Our photometric data is taken from the AAVSO International Database and our spectra come from a long term observing program organized by S. Howell using the Coude Feed Telescope at Kitt Peak National Observatory. Support for this work was provided by the NSF PAARE program to South Carolina State University under award AST-0750814. We thank the director of KPNO for his generous allocation of telescope time to this project over the years.

342.13

The Correlation Between the Photometric Variability and Spectra of Seven RV Tauri and Semi-Regular Stars

Eva Nesmith¹, S. Howell², D. Walter¹, J. Cash¹, K. Mighell²

¹South Carolina State University, ²National Optical Astronomy Observatory. Exhibit Hall

RV Tauri and Semi-regular variables are difficult to study because some of their behavior is non-periodic. It is believed they are in transition from the AGB to white dwarfs, but this evolution is not very well understood. We have initiated a multi-year study of their behavior in order to better understand the relationships between their period and luminosity and other observational quantities as well as establishing any correlations between pulsation phase and stellar properties. We present our preliminary results for seven stars, 3 RV Tauri and 4 Semi-regulars, obtained by studying the relationships and patterns, or lack thereof, between the variability of their light curves and corresponding changes in their spectra. The seven stars include R Sct, g Her, EU Del, Z UMa, V Vul, SX Her, and AC Her. The AAVSO International Database is the source of our photometric data. Our spectra come from a long term observing program organized by S. Howell using the Coude Feed Telescope at Kitt Peak National Observatory. Support for this work was provided by the NSF PAARE program to South Carolina State University under award AST-0750814. We thank the director of KPNO for his generous allocation of telescope time for this project over the years.

342.14

A Novel Approach to Solve Linearized Stellar Pulsation Equations

Christopher Bard¹, S. Teitler¹

¹University of Wisconsin.

Exhibit Hall

We present a new approach to modeling linearized, non-radial pulsations in differentially rotating, massive stars. As a first step in this direction, we consider adiabatic pulsations and adopt the Cowling approximation that perturbations of the gravitational potential and its radial derivative are negligible. The angular dependence of the pulsation modes is expressed as a series expansion of associated Legendre polynomials; the resulting coupled system of differential equations is then solved by finding the eigenfrequencies at which the determinant of a characteristic matrix vanishes. Our method improves on previous treatments by removing the requirement that an arbitrary normalization be applied to the eigenfunctions; this brings the benefit of improved numerical robustness.

The Calculation of H-beta Indices for delta Scuti Variable Stars

Kelsey Jorgenson¹, E. G. Hintz¹, M. D. Joner¹

¹Brigham Young Univeristy.

Exhibit Hall

The determination of fundamental stellar properties provides important information about particular groups of objects.

One such piece of information lies in the hydrogen beta index, gathered through spectral observations. The H-beta index is commonly used to measure surface temperature of stars as well as the age of stars or clusters. As such, it is a valuable piece of information for astronomical objects. In this study we present previously unpublished or updated H-beta index values for a set of delta Scuti variable stars. The original survey contained known delta Scuti stars north of -1° and brighter than 13th magnitude. This provided a sample of approximately 190 stars. Observations were made with the 1.2-m and 1.8-m telescopes at the Dominion Astrophysical Observatory.

342.16

The Properties of RR Lyrae Variables in M33

Soung-Chul Yang¹, A. Sarajedini¹, J. A. Holtzman², D. R. Garnett³

¹Univ. of Florida, ²New Maxico State University, ³801 W. Wheatridge Drive. Exhibit Hall

We present the results of an extensive survey of RR Lyrae stars in three fields along the major axis of the Triangulum Galaxy (M33). From images taken with the Advanced Camera for Surveys (ACS) Wide Field Channel (WFC) on-board the Hubble Space Telescope (HST) through two passbands (F606W and F814W), we have identified and characterized a total of 119 RR Lyrae variables (96 RRab (RR0) and 23 RRc(RR1)) in M33. Using the properties of 83 RR Lyrae stars (65 RRab and 18 RRc) in the innermost ACS field (hereafter DISK2), we find mean periods of = 0.553 ± 0.008 (error1) ± 0.05 (error2) and = 0.325 ± 0.008 (error1) ± 0.05 (error2), where the `error1' value represents the standard error of the mean and the `error2' value is based on the error of an individual RRL period calculated from our synthetic light curve simulations. The distribution of RRab periods and the frequency of RRc stars (Nc=n(c)/n(abc)=0.22) strongly suggest that these RR Lyraes follow the general characteristics of those in Oosterhoff type I Galactic globular clusters. The Oosterhoff I properties of the M33 field RR Lyrae stars agree well with those of RR Lyrae populations found in the M31 halo consistent with the past interaction history of these two galaxies.

342.17

Metal Abundance Calibration of the Ca II Triplet Lines in RR Lyrae Stars

Thomas Gomez¹, G. Wallerstein¹, W. Huang¹, G. Clementini², S. Andrievski³, V. Kovtyukh³ ¹University of Washington, ²Observatory of the University of Bologna, Italy, ³Observatory of the University of Odessa, Ukraine.

Exhibit Hall

The Gaia satellite is likely to observe thousands of RR Lyrae Stars a with small spectral range, between 8500 Å to 8750 Å, at a resolution of 10,000. In order to derive metallicity from Gaia, we are obtaining numerous spectra of RR Lyrae stars at a resolution of 30,000 with the APO 3.5m echelle spectrograph. We will correlate Ca II triplet abundances with Fe II abundances, analogous to Preston's (1959) use of Ca II K line to estimate metallicity in RR Lyrae Stars. We will then redrive these relations at the Gaia spectral resolution.

Period-Color Relations at Max/Min Light for RR Lyraes in the Sloan Digital Sky Survey

Anna Bontorno¹, M. Berke¹, S. Kanbur¹, C. Ngeow²

¹SUNY Oswego, ²National Central University, Taiwan.

Exhibit Hall

Using a sample of RR Lyraes discovered by the Sloan Digital Sky Survey, we construct Period-Color relations at maximum/minimum light in a range of colors from the SDSD. We find strong evidence that RR Lyraes have a flat PC relation at minimum light and have a color that gets bluer as the amplitude increases. We briefly discuss the use of such relations.

343

Extrasolar Planets: Characterization and Theory Poster Session *Exhibit Hall*

343.01

Determining Rotational Periods with Relative Photometry: V836 Tauri & BP Tauri Cailah DeRoo¹, L. Prato², B. Skiff², C. Crockett², N. Mahmud³, C. Johns-Krull³

¹Worcester Polytechnic Institute, ²Lowell, ³Rice University.

Exhibit Hall

Rotational periods for the T Tauri stars V836 Tau and BP Tau were determined using relative photometry in the B, V, and R filters. A rotational period of 7.0 days for V836 Tau was found and is consistent with other published periods. This variation in flux is likely caused by a combination of hot and cool spots on the star's surface. Initial analysis of one week's worth of data for the young star BP Tau revealed a rotational period of approximately 5.6 days; with the inclusion of all our data sets taken over 4 years we will obtain a more robust result. This research is part of a larger program with the goal of searching for exoplanets around stars in the Taurus-Auriga association. By comparing photometric rotation periods with radial velocity periods, variability caused by exoplanets rather than star spots can be identified. This research was supported by NSF grant number AST-1004107.

343.02

Exo-Planetary Transits of Limb Brightened Lines

Everett Schlawin¹, E. Agol², L. Walcowicz³, K. Covey¹, J. P. Lloyd¹

¹Cornell University, ²University of Washington, ³University of California at Berkeley. Exhibit Hall

Transit light curves for stellar continua have only one minimum and a "U" shape. By contrast, transit curves for optically thin chromospheric emission lines can have a "W" shape because of stellar limb-brightening. We calculate light curves for an optically thin shell of emission and fit these models to time-resolved observations of Si IV absorption by the planet HD209458b. We find that the best fit SiIV absorption model has R_p ,SiIV/ $R_* = 0.34 + 0.07 - 0.12$, similar to the Roche lobe of the planet. While the large radius is only at the limit of statistical significance, we develop formulae applicable to transits of all optically thin chromospheric emission lines.

A New and Expanded Homogeneous Analysis of Extrasolar Transiting Planets

Guillermo Torres¹, J. A. Carter¹, J. N. Winn², M. J. Holman¹, D. Fischer³, A. Sozzetti⁴ ¹Harvard-Smithsonian Center for Astrophysics, ²Kavli Institute for Astrophysics and Space Research, MIT, ³San Francisco State University, ⁴INAF – Osservatorio Astronomico di Torino, Italy. Exhibit Hall

We present early results from a new program to determine physical parameters of all known transiting exoplanets. The purpose of this program is to follow a strict, homogeneous methodology to analyze archival transit light curve data in order to make clear interpretations of the ensemble properties of transiting exoplanets. We describe our methodology, which includes a consistent treatment of stellar limb darkening, an improved transit light curve noise model that accounts for time-correlated stochastic noise, and a statistically robust assessment of stellar parameters based upon stellar evolution models and spectroscopic as well as photometric constraints. In addition, we describe an associated spectroscopic follow-up program that seeks to more precisely determine observable stellar parameters (e.g., effective temperature, surface gravity, and metallicity) for exoplanet host stars that may be used as priors in the aforementioned homogeneous analysis. This research is supported by the NASA/Origins Program, grant NNX09AF59G.

343.04

Multi-Transiting Systems and Exoplanet Mutual Events

Jared Coughlin¹, D. Ragozzine², M. J. Holman²

¹Villanova University, ²Harvard-Smithsonian Center for Astrophysics.

Exhibit Hall

Until recently, studies of transiting exoplanets- planets that cross in front of their host star- have focused almost exclusively upon systems where there is only one transiting planet. Those studies that have considered additional planets have mostly done so with the goal of determining the perturbing effects that additional planets would have upon the orbit, and therefore the light curve, of the transiting planet. This work considers, in detail, a specific type of event known as an exoplanet mutual event. Such events occur when one planet passes in front of another. While such events can occur whether or not these planets are transiting, predicting and understanding these events is best done in systems with multiple transiting planets. We estimate, through an ensemble simulation, how frequently exoplanet mutual events occur and which systems are most likely to undergo exoplanet mutual events. & https://www.area.com/area also investigate what information can be learned about not only the planets themselves but also the orbital architecture in such systems. We conclude that while ODT (overlapping double-transit) events occur with a much lower frequency than PPO (planet-planet occultation) events, ODT mutual events are capable of producing detectable signals, that Kepler will detect a few, and recommend that candidate systems for these events, such as KOI 191, be observed in short cadence(Steffen et. al 2010, Holman et. al 2010). This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 0754568 and by the Smithsonian Institution.

343.05

First Results from the Wesleyan Transiting Exoplanet Program

Marshall C. Johnson¹, E. M. Leiner¹, S. Redfield¹

¹Wesleyan University.

Exhibit Hall

We present results from the first six months of observations of the Wesleyan Transiting Exoplanet Program (WesTEP). A selection of exoplanet transits has been observed using the 24" Perkin Telescope at Wesleyan University's Van Vleck Observatory. The use of defocusing and manual guiding (as no autoguiding is available) has been explored to improve the quality of the data. These techniques allow the achievement of a photometric RMS as low as ~1 mmag. The dataset now includes more than two dozen transits, which we use to search for evidence of transit timing variations and refine the ephemerides of recently discovered planets. This research was funded by the NASA CT Space Grant Consortium.

343.06

The Wesleyan Hobby-Eberly High-resolution Exoplanetary Atmospheric Transmission Spectroscopy Survey (W[HE]²ATS²): First Results

Adam G. Jensen¹, S. Redfield¹, W. D. Cochran², M. Endl², L. Koesterke², T. Barman³ ¹Wesleyan University, ²University of Texas at Austin, ³Lowell Observatory. Exhibit Hall

We present the first results of W[HE]²ATS² (The Wesleyan Hobby-Eberly High-resolution Exoplanetary Atmospheric Transmission Spectroscopy Survey). To date, this survey has collected approximately 90 hours worth of high-resolution (R~60k) ground-based optical spectra with the 9.2m Hobby-Eberly Telescope, with additional observations in progress. The survey includes five different solar-type stellar systems with transiting hot Jupiters or Neptunes. Spectra are taken both in and out of transit; the two categories of observations are each coadded with the resulting coadded spectra differenced to search for absorption from resonance lines of alkali metals that are expected in these atmospheres. We will present our confirmation of previous detections of Na I absorption in HD 189733 and HD 209458 and present upper limits on and possible new detections of Na I and K I in these and other targets. In addition, we will describe the details and challenges of our data reduction and analysis. Finally, we will discuss our prospects for future work in searching for additional alkali metal lines and exospheric absorption. This work is supported by the National Science Foundation through an Astronomy and Astrophysics Research Grant (AST-0903573). The Hobby-Eberly Telescope is a joint project of the University of Texas at Austin, the Pennsylvania State University, Stanford University, Ludwig-Maximilians-Universität München, and Georg-August-Universität Göttingen and is named in honor of its principal benefactors, William P. Hobby and Robert E. Eberly.

343.07

CHARA Array Measurements of HR 8799 and Their Implications for the Imaged Companions

Ellyn K. Baines¹, R. J. White², T. Boyajian², J. Jones², M. Ireland³, H. A. McAlister², T. A. ten Brummelaar⁴, N. H. Turner⁴, J. Sturmann⁴, L. Sturmann⁴, S. T. Ridgway⁵

¹Naval Research Laboratory, ²Georgia State University, ³University of Sydney, Australia, ⁴The CHARA Array, ⁵National Optical Astronomy Observatory.

Exhibit Hall

Marois et al. announced they had imaged three planets around the star HR 8799 in 2008. Because the mass of the companions depends on the age of the system, Marois et al. used various techniques to estimate the star's age and settled on a range between 30 and 160 Myr, which translated to masses of 5-11 MJ for the b companion and 7-13 MJ for the c and d companions. Here we use interferometric observations to place constraints on the star's and companions' ages and masses by directly measuring the angular diameter of HR 8799 using the CHARA Array. This value, when combined with the Hipparcos parallax, leads to the star's physical radius and can be used to calculate the star's effective temperature. This then allows us to place the star on an H-R diagram to determine its age and mass, which in turn tells us more about the nature of the imaged companions.

Orbital Analysis of the HR 8799 Planetary System: Astrometric Characterization and Improvements Quinn M. Konopacky¹, B. A. Macintosh¹, C. Marois², T. S. Barman³, G. Laughlin⁴

¹LLNL, ²HIA, Canada, ³Lowell Observatory, ⁴University of California, Santa Cruz.

Exhibit Hall

We present new results on the potential orbital configuration of the HR 8799 planetary system. New astrometric analysis of imaging data from NIRC2 on the Keck II telescope has allowed us to correct biases in the astrometry caused primarily by the camera's focal plane mask. Correcting these biases has significantly improved the orbit fits to our astrometry. We use these fits, along with other information uncovered in new 2010 datasets, to shed light on the stability of this system over long timescales. Portions of this work were performed

under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. This work is supported by the NASA Origins Program.

343.09

Exploring The Detectability of Terrestrial Exoplanet Characteristics

Nicole Evans¹, V. S. Meadows¹, S. D. Domagal-Goldman²

¹University of Washington, ²NASA HQ.

Exhibit Hall

Of the 400+ extrasolar planets that have been discovered to date, the vast majority are massive gas giants. This is largely due to the inherent difficulty of detecting terrestrial planets, which are small and faint by comparison. Both NASA and ESA have proposed mission concepts for space-based observatories (Terrestrial Planet Finder [TPF] and Darwin, respectively) capable of detecting these planets by suppressing the light of their host stars, in order to discern the light reflected by the planetary companion. Following a successful detection, TPF/Darwin will then analyze the planet's spectrum to determine its chemical composition, and whether it may be capable of supporting life. Prior to the launch of such missions, we will need to understand the spectral characteristics of the planets we may find, and how detectable these characteristics will be. NASA's Virtual Planetary Laboratory (VPL) has generated synthetic spectra for a variety of possible planets, including the early and modern-day Earth, other planets in our solar system, and model planets around other stars. Using these spectra and a TPF-C simulator (provided by S. Heap and D. Lindler, GSFC), we have calculated the exposure times necessary to obtain the spectral resolution required to identify signs of habitability and life, such as the presence of oxygen and liquid water. By determining the detectability of key spectral characteristics within the limitations of a mission concept such as TPF, we hope to evaluate and quantify what is essential for a successful future planet-characterizing mission. Support for this work was provided by the NASA Astrobiology Institute's Virtual Planetary Laboratory.

343.10

Design Of A Space-borne, Mid-IR Exoplanet Imager

David C. Hyland¹, D. Khussainov¹, H. Kim¹, M. Kim¹, J. P. Quinn¹

¹Texas A&M University.

Exhibit Hall

This paper describes a novel design for a space-borne system capable of producing multi-pixel, mid-IR images of a class of exosolar planets. Our design considerations focus on "super-Earths" in the habitable zones of M-class stars. This stellar class is the most abundant and the contrast ratio in the mid infrared for habitable zone super-Earths is most favorable. Although such planets will be tidally locked, recent studies have suggested that atmospheric collapse on the dark side may not occur and conditions favorable to life may exist near the terminators. The goal of the design is to create images having 20
pixels across the diameter of planets within 10 parsecs of Earth. To obtain unblurred images, the total imaging time must be less than $1/20^{\text{th}}$ the planet rotation period. The tidally locked condition helps us meet this requirement since the orbital/rotational period is some tens of days.

The resulting design consists of a constellation of 24 light collecting units located near the Earth-Sun L2 libration point. Each light collector is a truss-mounted nulling interferometer, the output of which (containing only planet emissions) is recorded by a photodetector. Digitized photodetector data from all light collecting units is then transmitted and processed to compute the image using the Intensity Correlation Imaging (ICI) approach. ICI technology exploits the Brown-Twiss effect to produce ultra-fine resolution images with spatially distributed light collecting apertures. While greatly extending the sensitivity of the Brown-Twiss effect, ICI offers many advantageous features for planet imaging. It does not require the propagation of collected light beams to combiner units. Nor does it require nanometer-level control of, nor knowledge of the relative positions of the collector units. We show via detailed simulations that images of unprecedented resolution can be produced in a day with a Golay formation of relatively straightforward collector units.

343.11

Observing The Super-Earth GJ1214b In The Face Of Stellar Variability

Zachory K. Berta¹, D. Charbonneau¹, J. Irwin¹, J. Bean¹, C. Burke¹, P. Nutzman¹, E. Falco² ¹Harvard University, ²Smithsonian Astrophysical Observatory.

Exhibit Hall

Discovered by the MEarth Survey, GJ1214b is a 2.7 Earth radius, 6.6 Earth mass exoplanet that transits a nearby M dwarf only 13 pc away. The star exhibits a 1% photometric variability, most likely induced by stellar spots, that could potentially complicate follow-up studies of the planet's atmosphere and interior structure. We present the results of new photometric monitoring of GJ1214, with which we estimate the stellar rotation period, place limits on the effects of the spots on observed transmission spectra, and search for additional transiting planets in the system.

343.12

"Some Like it Hot" - Evidence for the Shrinking Orbit of the 2.2-day Transiting Hot Jupiter Exoplanet HD 189733b - Evidence of Transfer of Planet Orbital Momentum to its Host Star

Thomas Santapaga¹, E. F. Guinan¹, R. Ballouz¹, S. G. Engle¹, L. Dewarf¹

¹Villanova University.

Exhibit Hall

HD189733A is a K2V star that has attracted much attention because it hosts a transiting, hot Jupiterexoplanet. HD189733b has one of the shortest known orbital-periods (P = 2.22-days) and is only 0.031AU from its host star (Buchy et al. 2005). Based on measurements of the K2V star's P(rot) from starspot-modulations of ~12-d, coronal Lx ~10²⁸ ergs/s, and chromospheric Ca II-HK emission, indicate an age ~0.6 -1.0 Gyr - inferred from our rotation-age-activity relations. However, this age is discrepant with an older-age inferred from the star's low Lithium-abundance (~1/10 Solar.). However, the agerotation-activity determination assumes no tidal-effects from close companions- such as close planet. Recently Gaspar et al. (2006) discovered a dM4 companion star (HD 189733 B: ~12'' distance to the Kdwarf). X MM-Newton observations of the HD 189733 A&B carried out recently by Pilliteri et al. (2010), surprisingly revealed that HD 189733B shows no X-ray emission, with an upper limit of ~9*10²⁶ ergs/s. Using activity-age relationships for dM-stars, we expected a Lx of an order of magnitude higher for age <1.0 Ga. This apparent discrepancy can be resolved by the supposition that the K2V-star has been spunup by its nearby planetary companion, and that its age determined from activity-rotation relationships is invalid. This supposition is supported by the recent photometry by the Kepler for 300+ exoplanet candidate systems discovered thus far (Borucki et al. 2010). The analysis these data have reveal that tidal locking between the planet and host star has occurred for a significant number of exoplanet with short orbital periods. We explain the fast rotation of the K2 star via the transfer of the planet's orbital angular momentum to the star via tidal interactions. The significance of these finding with respect to the evolution of planetary systems is discussed.

This work is partially supported by NSF/RUI grant AST-1009903.

343.13

Combining Secondary Eclipse and Phase Variation Mapping of Transiting Exoplanets: A 2-D Map of HD189733b at 8 Micron

Carl Majeau¹, N. B. Cowan², E. Agol³

¹Columbia University, ²Northwestern University, ³University of Washington. Exhibit Hall

It has previously been proposed that the secondary eclipse light curve of a transiting exoplanet can be used to make a map of its day-side brightness. We examine the methods by which we might extract such a map, focusing on two particular methods, the first utilizing regularization and second spherical harmonics. We detail the assumptions made and limitations inherent in each, and in doing so rule out regularization as an acceptable method. We show that the spherical harmonic method may be easily generalized to include phase variation data. We then apply the spherical harmonic method to the Spitzer eclipse data presented by Agol et. al. (2010) and the phase variation data used by Knutson et. al. (2007), obtaining a rough 2-D map of the planet at 8 micron. We also apply the method to simulated data to explore the factors governing map quality. Finally, we discuss the success of the application, compare the results to previous work in mapping and modeling Hot Jupiters, and ask what observational advancements would be required to improve map quality and detail.

343.14

Clouds On A Cold Planet: FIRE Spectroscopy Of Ross 458C

Adam J. Burgasser¹, R. A. Simcoe², J. J. Bochanski³, D. Saumon⁴, E. E. Mamajek⁵, M. C. Cushing⁶, M. S. Marley⁷, C. McMurtry⁵, J. L. Pipher⁵, W. J. Forrest⁵

¹UCSD/MIT, ²MIT, ³Pennsylvania State University, ⁴Los Alamos National Laboratory, ⁵University of Rochester, ⁶NASA JPL, ⁷NASA Ames.

Exhibit Hall

Ross 458C is a widely-separated (1100 AU), faint companion to the nearby M0.5 Ve + M7 Ross 458AB binary, identified in the UKIDSS survey by Goldman et al. and Scholz and suspected by both of being a young brown dwarf. We obtained near-infrared spectroscopy of this source with the newly-commissioned Folded-Port Infrared Echellette (FIRE) at the Magellan Telescopes, which revealed the presence of strong methane and water absorption consistent with a T8 dwarf. The age of this system (150-800 Myr) and the low luminosity of the companion (log Lbol/Lsun = -5.62 ± 0.03) indicate a mass at or below the deuterium burning limit. This is verified through atmospheric model fits to the spectral data, which indicate a low temperature (635 [+25,-35] K), a low surface gravity (log g ~ 4 cgs) and a model-dependent mass of <=6 Jupiter masses. The spectral models further indicate that condensate clouds are present in the atmosphere of Ross 458C, in contrast to results for other cold T dwarfs. These results provide further evidence that clouds are an important opacity source in the spectra of young substellar objects, from planetary-mass brown dwarfs in young clusters to directly-imaged exoplanets. Moreover, its low mass, cool atmosphere and physical association with a stellar system give Ross 458C all of the trappings of a planet, albeit one whose cosmogony may not conform with current planet formation theories.

This result includes data gathered with the 6.5-m Magellan Telescopes located at Las Campanas

Observatory, Chile. Support for the modeling work of D.S. was provided by NASA through the Spitzer Science Center.

343.15

On The Possibility of Enrichment and Differentiation in Gas Giants During Birth by Disk Instability Aaron C. Boley¹, R. H. Durisen²

¹University of Florida, ²Indiana University. Exhibit Hall

We investigate the coupling between rock-size solids and gas during the formation of gas giant planets by disk fragmentation in the outer regions of massive disks. In this study, we use three-dimensional radiative hydrodynamics simulations and model solids as a spatial distribution of particles. We assume that half of the total solid fraction is in small grains and half in large solids. The former are perfectly entrained with the gas and set the opacity, while the latter are allowed to respond to gas drag forces. To explore the maximum effects of gas-solid interactions, we first consider 10cm-size particles. We then compare these results to a simulation with 1km-size particles, which explores the low-drag regime.We show that (1) disk instability planets have the potential to form large cores due to aerodynamic capturing of rock-size solids in spiral arms before fragmentation; (2) that temporary clumps can concentrate tens of $M \oplus$ of solids in very localized regions before clump disruption; (3) that the formation of permanent clumps, even in the outer disk, is dependent on the opacity; (4) that nonaxisymmetric structure in the disk can create disk regions that have a solids-to-gas ratio greater than unity; (5) that the solid distribution may affect the fragmentation process; (6) that proto-gas giants and proto-brown dwarfs can start as differentiated objects prior to the H2 collapse phase; (7) that spiral arms in a gravitationally unstable disk are able to stop the inward drift of rock-size solids, even redistributing them to larger radii; and, (8) that large solids can form spiral arms that are offset from the gaseous spiral arms.

ACB's support was provided in part under contract with the California Institute of Technology (Caltech) funded by NASA through the Sagan Fellowship Program. RHD was supported by NASA Origins of Solar Systems grant NNX08AK36G.

343.16

Constraining the role of Tidal Forces in Exoplanet Systems Bradley M. Hansen 1

¹UC, Los Angeles.

Exhibit Hall

Tidal forces are clearly important in determining the parameters of short orbital period exoplanet systems. Yet, there is still uncertainty over the magnitude of the effects. We will discuss attempts to constrain the strength of tidal interactions by searching for a consistent description that covers the many, diverse combinations of planets and host stars.

343.17

The Potential for Extreme Mass Loss on Water Dominated Super Earths $\mathsf{Eric}\ \mathsf{Lopez}^1$

¹UC Santa Cruz.

Exhibit Hall

Planet formation models predict that significant numbers of ice dominated Super-Earths should form beyond the snow line, and that some fraction of these will then migrate or scatter inwards to highly irradiated orbits. We examine the potential for extreme mass loss on such planets due to XUV absorption and tidal heating.

343.18 **Resonant Capture of Exoplanets Into the 3:2 Mean Motion Resonance Richard Ruth**¹, A. V. Moorhead¹, E. B. Ford¹

¹University of Florida.

Exhibit Hall

Doppler observations have shown HD 45364 to harbor a multiple planet system with a 0.18 M_{Jup} planet interior to a 0.66 M_{Jup} planet. The orbital periods of these planets suggest that the system is in a 3:2 MMR (Correia et al. 2009). If we assume that these planets migrated through a gaseous protoplanetary disk into the 3:2 MMR observed today, then the current orbital properties can constrain the properties of the protoplanetary disk. We perform numerical experiments to explore the possible dynamical origins of the HD 45364 system. Using the FARGO hydrodynamic code (Masset 2000), we investigate to what degree disk parameters (e.g., viscosity and surface density profiles) dictate the final configuration of such systems.

Our numerical experiments frequently result in planetary systems participating in the 2:1 or 3:2 MMR's. For systems with a larger initial separation, MMRs are less frequent. We explore a range of disk parameters, but find none of these resulted in systems migrating through the 3:2 MMR. Higher disk viscosities led to longer-lived resonances. We present an example of disk parameters that results in a stable 3:2 MMR configuration (for integration time exceeding the viscous timescale of the disk) and is insensitive to initial position of the planets along their orbits.

343.19

Test Particle Stability in Exoplanet Systems

Shane Frewen¹, B. M. Hansen¹

¹UCLA.

Exhibit Hall

Astronomy is currently going through a golden age of exoplanet discovery. Yet despite that, there is limited research on the evolution of exoplanet systems driven by stellar evolution. In this work we look at the stability of test particles in known exoplanet systems during the host star's main sequence and white dwarf stages. In particular, we compare the instability regions that develop before and after the star loses mass to form a white dwarf, a process which causes the semi-major axes of the outer planets to expand adiabatically. We investigate the possibility of secular and resonant perturbations resulting in these regions as well as the method of removal of test particles for the instability regions, such as ejection and collision with the central star. To run our simulations we used the MERCURY software package (Chambers, 1999) and evolved our systems for over 10⁸ years using a hybrid symplectic/Bulirsch-Stoer integrator.

343.20

Differential Evolution MCMC: An Algorithm for Bayesian Parameter Estimation of Multi-planet Systems

Benjamin Nelson¹, M. J. Payne¹, E. B. Ford¹

¹University of Florida.

Exhibit Hall

For single-planet or weakly-interacting planetary systems, Markov chain Monte Carlo (MCMC) and the Metropolis-Hastings algorithm have gained widespread use for interpreting Doppler and transit observations. At least 15 of the ~50 extrasolar multi-planet systems appear to be in or near a meanmotion resonance. Some and perhaps most of these systems undergo planet-planet interactions on the observing timescale. Interpreting Doppler observations of such systems requires using self-consistent N-body integrations and exploring a high-dimensional (~7 x number of planets) parameter space that can

have complex parameter dependencies. We present the Differential Evolution MCMC (DEMCMC) algorithm for sampling from the posterior probability distribution for planet masses and orbital parameters. DEMCMC improves upon the random walk proposal distribution of the traditional MCMC by using an ensemble of Markov chains to adaptively improve the proposal distribution. DEMCMC can sample more efficiently from high-dimensional parameter spaces that have strong correlations between model parameters. We provide an overview of the algorithm, along with results of algorithm tests for accuracy and performance. We present early results from the application to previously announced multi-planet systems.

343.21

N-Body Simulations for Exoplanet Systems

Jessamyn Allen¹, G. Marcy¹, Kepler Science Team

¹University of California, Berkeley.

Exhibit Hall

We present N-body simulations of a multi-transiting system from the NASA Kepler mission. The detection rate of exoplanet candidates is rapidly increasing since the launch of Kepler in 2009. Kepler detection, often supported by follow-up radial velocity measurements, generates evidence for multiplanet systems, but further confirmation is sometimes required. We use N-body simulations to explore the dynamical interactions and the long-term stability of Kepler multi-transiting system KOI-82 using the Mercury integrator (written by J. Chambers). For systems where few initial parameters are known, such as planetary radii, orbital periods and central body mass calculated from transit light curves, densities and eccentricities can be constrained by whether stability holds. We have tested our N-body code against the known mean motion resonance and secular resonance effects in the GJ 876 system, including the apsidal corotation. N-body simulations allow the exploration of such planetary resonance and evolution, while also having the potential to be coupled with other programs to simulate transit light curves, calculate transit timing variations and possibly detect moons around exoplanets. We will present a dynamical analysis of the interactions and stability of the multi-transiting planet system from Kepler, KOI-82.

343.22

Secular Behavior of Exoplanetary Systems: Self-Consistency and Comparisons With The Planet-Planet Scattering Hypothesis

Miles L. Timpe¹, R. Kopparapu², R. Barnes¹, S. N. Raymond³, R. Greenberg⁴, N. Gorelick⁵ ¹University of Washington, ²Penn. State University, ³University of Colorado, ⁴University of Arizona, ⁵Google.

Exhibit Hall

Planet-planet scattering has been suggested as a mechanism to explain the disproportionate number of planet-planet pairs found to lie on or near an apsidal separatrix, in which one planet's eccentricity periodically drops to near-zero. We present the results of numerical simulations of 2-planet systems having arisen from dynamically unstable 3-planet systems. We show that the distribution of near-separatrix systems arising after an instability is consistent with the observed systems, further strengthening the planet-planet scattering hypothesis.

We also note that many observed systems have been found near their extreme eccentricity values. Such a pattern may suggest a bias in exoplanet observations, as planets should have an equal probability of being discovered at any point in their secular cycle. We test this possibility by numerically integrating known multiplanet systems and determining the relative time each planet spends in a given eccentricity range and then comparing this distribution of eccentricity values to the observational uncertainty. We find that planets tend to spend more time near their minimum and maximum values as they represent turning points in the oscillations. Moreover, the uncertainties for many eccentricities are so large that we cannot make strong statements regarding the possibility that planets are being discovered at their extreme eccentricities too often. However, as uncertainties become smaller and more multiplanet systems are discovered, this potential bias should be revisited.

343.23

Emission of Alfven Waves by Planets in Close Orbits

Keith B. MacGregor¹, M. H. Pinsonneault²

¹HAO/NCAR, ²Ohio State Univ..

Exhibit Hall

We examine the electrodynamics of a conducting planet orbiting within a magnetized wind that emanates from its parent star. When the orbital motion differs from corotation with the star, an electric field exists in the rest frame of the planet, inducing a charge separation in its ionosphere. Because the planet is immersed in a plasma, this charge can flow away from it along the stellar magnetic field lines it successively contacts in its orbit. For sufficiently rapid orbital motion, a current system can be formed that is closed by Alfvenic disturbances that propagate along field lines away from the planet. Using a simple model for the wind from a Sun-like star, we survey the conditions under which Alfven wave emission can occur, and estimate the power radiated in the form of linear waves for a range of stellar, planetary, and wind properties. For a Jupiter-like planet in a close (a < 0.10 AU) orbit about a solar-type star, the emitted wave power can be as large as 10²⁷ erg/s. While only a small influence on the planet's orbit, a wave power of this magnitude may have consequences for wind dynamics and localized heating of the stellar atmosphere. NCAR is sponsored by the NSF.

343.24

Magnetic Field Signature Of Super Earths

Ana-Maria Piso¹, S. Seager¹, P. Rebusco¹

¹Massachusetts Institute of Technology.

Exhibit Hall

We study the magnetic field and the planet-star interactions of super Earths, exoplanets with masses between 1 and 10 times the mass of the Earth. We use scaling laws to model the power dissipated due to the magnetic reconnection between the planetary and star magnetic fields. We then apply our model to the recently discovered super Earth GJ 1214 b. We find that the radio emission from the planet can be detectable with ground based instruments (i.e. LOFAR) if GJ 1214 b is a water-rich planet, is not likely to be detectable if GJ 1214 b has an icy, Neptune-like structure, and can be detectable in extreme cases (i.e. a large core radius or large magnetic diffusivity) if GJ 1214 b is a rocky planet. We further generalize our results to other super Earths. We find that, for water rich planets within 10 parsecs away, the peak radio emission frequency is larger than 10 MHz and detectable with LOFAR. Rocky planets have peak frequencies that are only detectable if the core radius or the magnetic diffusivity of the core are large enough. Mini-Neptunes generally have peak emission frequencies lower than 10 MHz and are thus unlikely to be detected from Earth.

343.25

Radio Observations of HD 80606 Near Planetary Periastron

T. Joseph W. Lazio¹, P. D. Shankland², W. M. Farrell³, D. L. Blank⁴

¹JPL, ²USNO, ³NASA/GSFC, ⁴James Cook Univ., Australia.

Exhibit Hall

This paper reports Very Large Array (VLA) observations at 325 and 1425 MHz during and near the periastron passage of HD 80606b on 2007 November 20. We obtained 3σ limits of 1.7 mJy and 48 microJy at 325 and 1425 MHz, respectively, equivalent to planetary luminosity limits of 2.3 x 10^{24} erg/s

and 2.7 x 10²³ erg/s. Unfortunately, these are orders of magnitude above the Jovian value (at 40 MHz) of 2 x 10¹⁸ erg/s. The motivation for these observations was that the planetary magnetospheric emission is driven by a stellar wind-magnetosphere interaction so that the planetary luminosity should be elevated near periastron. We estimate that, near periastron, HD 80606b might be as much as 3000x more luminous than Jupiter. Transit observations of HD 80606b provide stringent constraints on the planetary mass and radius, and, because of the planet's highly eccentric orbit, its rotation period is likely to be "pseudo-synchronized" to its orbital period, allowing a robust estimate of the former. Consequently, we are able to make a robust estimate of the emission frequency of the planetary magnetospheric emission and find it to be around 60--90 MHz. While this is too low for our reported observations, we compare HD 80606b to other high eccentricity systems and assess the detection possibilities for both near-term and more distant future systems. Of the known high eccentricity planets, only HD 80606b is likely to be detectable, as the others (HD 20782Bb and HD 4113) are both lower mass and longer rotational periods, which imply a weaker magnetic field strengths. Both the forthcoming "EVLA low band" system, which will operate as low as 65 MHz, and the Low Frequency Array (LOFAR) may be able to improve upon our planetary luminosity limits for HD 80606b, and do so at a more optimum frequency.

344

Computation, Data Handling, Image Analysis Poster Session *Exhibit Hall*

344.01

User Movement Across the Zooniverse Cory Lehan¹, P. Gay¹ ¹*SIUE Astronomy / New Media.*

Exhibit Hall

The Zooniverse, a collection of projects centered around everyday people contributing to massive amounts of citizen science, has seen many expansions over its lifetime. When a new project is added, new users come into the Zooniverse and may move to participate in older projects. Some old users will stay with the same project(s) as before, some will move to the new project, and some will participate in both. We model the behaviors of new and old members of the Zooniverse when new projects arise to get a better understanding of the Zooniverse user base and citizen science in general. We present both a data visualization of long term trends and a numerical analysis of the frequencies at which different behaviors appear.

344.02

6-degrees of Astronomical Separation

Pamela L. Gay¹

¹Southern Illinois University Edwardsville / Astronomy Cast. Exhibit Hall

In this paper we present a data visualization of how the citizen scientists in the Zooniverse citizen science project and astronomy content consumers associated with the Astronomy Cast and 365 Days of Astronomy podcasts can be linked to other astronomy programs via their social connections in Twitter. This visualization shows how some people select to engage in a myriad of astronomy projects, while other focus narrowly on just one online community. We also show how professional astronomy online entities (both real people, and the avatars of missions and projects) engage with other astronomy projects as a form of social networking. The result of the project is a network showing the structure of the astronomical community within the twitterverse and other online, astronomy-specific projects.

344.03

The Canadian Astronomy Data Centre

Nicholas M. Ball¹, D. Schade¹, Canadian Astronomy Data Centre

¹*Herzberg Institute of Astrophysics, Canada.*

Exhibit Hall

The Canadian Astronomy Data Centre (CADC) is the world's largest astronomical data center, holding over 0.5 Petabytes of information, and serving nearly 3000 astronomers worldwide. Its current data collections include BLAST, CFHT, CGPS, FUSE, Gemini, HST, JCMT, MACHO, MOST, and numerous other archives and services. It provides extensive data archiving, curation, and processing expertise, via projects such as MegaPipe, and enables substantial day-to-day collaboration between resident astronomers and computer specialists. It is a stable, powerful, persistent, and properly supported environment for the storage and processing of large volumes of data, a condition that is now absolutely vital for their science potential to be exploited by the community. Through initiatives such as the Common Archive Observation Model (CAOM), the Canadian Virtual Observatory (CVO), and the Canadian Advanced Network for Astronomical Research (CANFAR), the CADC is at the global forefront of advancing astronomical research through improved data services. The CAOM aims to provide homogeneous data access, and hence viable interoperability between a potentially unlimited number of different data collections, at many wavelengths. It is active in the definition of numerous emerging standards within the International Virtual Observatory, and several datasets are already available. The CANFAR project is an initiative to make cloud computing for storage and data-intensive processing available to the community. It does this via a Virtual Machine environment that is equivalent to managing a local desktop. Several groups are already processing science data. CADC is also at the forefront of advanced astronomical data analysis, driven by the science requirements of astronomers both locally and further afield. The emergence of 'Astroinformatics' promises to provide not only utility items like object classifications, but to directly enable new science by accessing previously undiscovered or intractable information. We are currently in the early stages of implementing Astroinformatics tools, such as machine learning, on CANFAR.

344.04

The Canadian Advanced Network For Astronomical Research

Sebastien Fabbro¹, Canadian Advanced Network For Astronomical Research

¹University of Victoria, Canada.

Exhibit Hall

The Canadian Advanced Network For Astronomical Research (CANFAR) is an operational system for the delivery, processing, storage, analysis, and distribution of very large astronomical data sets. CANFAR is a cyber-infrastructure combining research network, grid processing and storage resources and a data centre, into a unified storage and processing system. For processing, the project has combined features of the grid and cloud processing models by providing a self-configuring virtual cluster deployed on multiple cloud clusters. The CANFAR processing service makes use of many technologies from the grid, cloud and Virtual Observatory communities. Here we describe the different CANFAR components and how it lets groups of astronomers to easily deploy multiple data reduction pipelines. We also show a few examples of the applications on large archived data sets from the Canadian Astronomy Data Centre.

344.05 New Data and Services at the NASA/IPAC Infrared Science Archive (IRSA)

Justin Howell¹, S. Groom¹, H. Teplitz¹

¹IPAC/Caltech.

Exhibit Hall

The NASA/IPAC Infrared Science Archive (IRSA) serves science data sets from NASA's infrared and submillimeter projects and missions. IRSA is the long term home for data from the Spitzer Space Telescope, through the Spitzer Heritage Archive (SHA). The SHA interface now replaces the "Leopard" software as the tool to access data from Spitzer. It provides complete access to data from both the warm and cryogenic data missions, together with enhanced science products produced by the Spitzer Science Center and the Legacy teams.

IRSA is undergoing a period of rapid archive expansion with the addition of new data sets, along with new tools for serving them. In Spring 2011, IRSA will be the archive center for the Wide-field IR Survey Explorer (WISE) satellite, and will serve the Early Release Science Catalog from ESA's Planck mission to the US community. We highlight recent data additions to IRSA. We describe work underway on new multi-mission web interfaces for data access at IRSA. IRSA can be found at http://irsa.ipac.caltech.edu .

344.06

Chandra Footprint Service: Visualizing Chandra's Sky Coverage Aaron Watry¹

¹Smithsonian Astrophysical Observatory. Exhibit Hall

The Chandra Footprint Service provides a visual interface to observational data in the public Chandra Data Archive and the Chandra Source Catalog. Users of the service are given the ability to directly see which areas of the sky have been observed by the Chandra X-Ray Observatory for any target of interest. The browser-based interface provides visualization of the sky coverage of Chandra instruments for any region of the sky along with tabular data for observations. The service provides an interactive clientbased overlay of the instrument region data on top of a Sloan Digital Sky Survey background image, previews of observation images, access to data products, and access to the VOTable data used to create the interface. This work presents the interface and capabilities of the service and the technologies that make it possible.

344.07

The New MAST Portal

Alberto Conti¹, A. Rogers¹, T. Donaldson¹, B. Shiao¹, C. Christian¹, K. Levay¹, R. White¹, MAST Team ¹STScl.

Exhibit Hall

Archival science is having a major impact on astronomy and will continue to do so for the foreseeable future. The Multi-mission Archive at Space Telescope (MAST) is in the process of developing a new portal aimed specifically at facilitating access to high-quality, comprehensive, multi-wavelength data and related search results. Our goal is to adapt and evolve in response to community input, and provide the astronomical community with a rich, modern set of tools for data mining, data retrieval, and data analysis.

344.08

The NASA/IPAC Extragalactic Database (NED): Enhanced Content and New Functionality Marion Schmitz¹, K. Baker¹, B. Chan¹, H. Corwin, Jr.¹, R. Ebert¹, C. Frayer¹, G. Helou¹, C. LaGue¹, T. Lo¹, B. Madore¹, J. Mazzarella¹, O. Pevunova¹, I. Steer¹, S. Terek¹ ¹Caltech.

Fxhibit Hall

New content and science functionality of the NASA/IPAC Extragalactic Database (NED) are presented. New content includes 230,000 objects from the SWIRE catalog (2008MNRAS.386..697R), 100,000 Chandra Source Catalog v1.1 objects (2010ApJS..189...37E), 13,000 objects in the Extragalactic Distance Database (EDD-2009AJ....138.1938C), 6,000 objects and redshifts from the WINGS survey (2009A&A...495..707C) plus tens of thousands of objects reported in the current refereed literature. The NED-D Distance database has been updated to contain 36,000 distances for 9,000 galaxies. The searchable Galaxy Classification service released in January 2010 continues to grow with past and current published data offering Galaxy Morphologies in both optical and radio regimes, Activity and Spectral Types, Luminosity Classes and more. New functionality is introduced that enables users to control what parameters are returned for objects selected with constraints on galaxy classifications. In addition to selection or deselection of basic source parameters such as coordinates and redshift, the Customized Output feature also enables users to extract detailed measurements such as multi-wavelength photometry and diameters (as available), all from a single query. The resultant data table lists each requested parameter in a separate column, one row for each object in the sample, making further analysis more convenient. In the coming year this capability will be expanded to provide more dynamic and flexible options, and it will be extended to other types of NED queries. Hardware and software modifications will also allow more frequent updates of the NED database. Researchers are encouraged to visit the NED exhibit booth at this meeting for a demonstration and further information. NED is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

344.09

Sharing the Sky: High Performance Exploration for Survey Astronomy

Ian Smith¹, A. Connolly¹, S. Krughoff¹, R. Gibson¹, C. Sayres¹ ¹University of Washington.

Exhibit Hall

Current astronomical surveys have yielded hundreds of terabytes of images and catalogs spanning many decades of the electromagnetic spectrum. Providing access to these data sets will facilitate a broad range of multi-wavelength science programs. Even when observatories provide user-friendly web interfaces, exploring these data resources remains a complex and daunting task. How can we make the interaction with this data simple, intuitive and customizable. Here we present a new approach to data interaction that builds on emerging social networking technologies used in web-based tools (i.e. widgets or gadgets). We demonstrate how the gadgets we developed can communicate and share information, enabling users to visualize and interact with data through multiple, simultaneous views. We also show

how new web-based applications for accessing and visualizing data can be easily generated, and how, by linking these tools together, we can build integrated and powerful data analysis frameworks.

344.10

Mining the GBT Metadata Archive: Statistics on Radio Frequency Use, 2002 - 2010 Michael Blatnik¹, A. W. Clegg², C. Beaudet³, R. J. Maddalena³

¹Lynchburg College, ²National Science Foundation, ³National Radio Astronomy Observatory. Exhibit Hall

The metadata from all standard archived Robert C. Byrd Green Bank Telescope (GBT) data have been mined to develop accurate and detailed statistics on radio frequency use. The purpose of the exercise is to help answer several long-standing questions within the radio astronomy spectrum management community: What fraction of observing time is actually spent within exclusive allocated radio astronomy bands, within bands shared with transmitting services, or in bands that have no allocation to the radio astronomy service? To answer these questions, we developed an automated data mining system (which leveraged existing data analysis tools) and applied it to 6 TB of files in the GBT data archive. The data spanned the range August 30, 2002 - July 24, 2010. Data acquired prior to that pre-dated the standard GBT "production-mode" archive format, and data acquired after that range will be added to the analysis on a yearly basis.

GBT data from the antenna, receiver, IF, and other systems are acquired asynchronously in separate FITS files, which must then be time-matched and merged into a single data file to extract the necessary metadata. The automated system merged the FITS files and extracted 73 available parameters, such as sky frequency, bandwidth, azimuth, elevation, RA, DEC, system temperature, and many others. All data that generated full standard FITS data sets, including calibration and drift scans, were included in the statistics. Some observing modes, such as pulsar observations using custom backends without the parallel use of a standard GBT backend, could not be incorporated in the initial analysis. This presentation will summarize observing statistics that are relevant to spectrum management activities, and will provide answers to the above questions. Future work should include extending this analysis to other major radio astronomy facilities, such as Arecibo, the VLA, and the VLBA.

344.11

Extracting meaning from astronomical telegrams

Matthew Graham¹, L. Conwill¹, S. G. Djorgovski¹, A. Mahabal¹, C. Donalek¹, A. Drake¹

¹Caltech. Exhibit Hall

The rapidly emerging field of time domain astronomy is one of the most exciting and vibrant new research frontiers, ranging in scientific scope from studies of the Solar System to extreme relativistic astrophysics and cosmology. It is being enabled by a new generation of large synoptic digital sky surveys - LSST, PanStarrs, CRTS - that cover large areas of sky repeatedly, looking for transient objects and phenomena. One of the biggest challenges facing these is the automated classification of transient events, a process that needs machine-processible astronomical knowledge. Semantic technologies enable the formal representation of concepts and relations within a particular domain. ATELs (http://www.astronomerstelegram.org) are a commonly-used means for reporting and commenting upon new astronomical observations of transient sources (supernovae, stellar outbursts, blazar flares, etc). However, they are loose and unstructured and employ scientific natural language for description: this makes automated processing of them - a necessity within the next decade with petascale data rates - a challenge. Nevertheless they represent a potentially rich corpus of information that could lead to new and valuable insights into transient phenomena.

This project lies in the cutting-edge field of astrosemantics, a branch of astroinformatics, which applies

semantic technologies to astronomy. The ATELs have been used to develop an appropriate concept scheme - a representation of the information they contain - for transient astronomy using aspects of natural language processing. We demonstrate that it is possible to infer the subject of an ATEL from the vocabulary used and to identify previously unassociated reports.

344.12

Astronomy In The Cloud: Using Mapreduce For Image Coaddition

Keith Wiley¹, A. Connolly¹, J. Gardner¹, S. Krughoff¹, M. Balazinska¹, B. Howe¹, Y. Kwon¹, Y. Bu¹ ¹University of Washington.

Exhibit Hall

In the coming decade, astronomical surveys of the sky will generate tens of terabytes of images and detect hundreds of millions of sources every night. The study of these sources will involve computational challenges such as anomaly detection, classification, and moving object tracking. Since such studies require the highest quality data, methods such as image coaddition, i.e., registration, stacking, and mosaicing, will be critical to scientific investigation. With a requirement that these images be analyzed on a nightly basis to identify moving sources, e.g., asteroids, or transient objects, e.g., supernovae, these datastreams present many computational challenges. Given the quantity of data involved, the computational load of these problems can only be addressed by distributing the workload over a large number of nodes. However, the high data throughput demanded by these applications may present scalability challenges for certain storage architectures. One scalable data-processing method that has emerged in recent years is MapReduce, and in this paper we focus on its popular open-source implementation called Hadoop. In the Hadoop framework, the data is partitioned among storage attached directly to worker nodes, and the processing workload is scheduled in parallel on the nodes that contain the required input data. A further motivation for using Hadoop is that it allows us to exploit cloud computing resources, i.e., platforms where Hadoop is offered as a service. We report on our experience implementing a scalable image-processing pipeline for the SDSS imaging database using Hadoop. This multi-terabyte imaging dataset provides a good testbed for algorithm development since its scope and structure approximate future surveys. First, we describe MapReduce and how we adapted image coaddition to the MapReduce framework. Then we describe a number of optimizations to our basic approach and report experimental results compring their performance. This work is funded by the NSF and by NASA.

344.13

Automated Detection of Objects Based on Sérsic Profiles

Guillermo Cabrera¹, C. Miller², C. Harrison², E. Vera¹, T. Asahi¹ ¹Universidad De Chile, Chile, ²University of Michigan.

Exhibit Hall

We present the results of a new astronomical object detection and deblending algorithm when applied to Sloan Digital Sky Survey data. Our algorithm fits PSF-convolved Sérsic profiles to elliptical isophotes of source candidates. The main advantage of our method is that it minimizes the amount and complexity of real-time user input relative to many commonly used source detection algorithms. Our results are compared with 1D radial profile Sérsic fits. Our long-term goal is to use these techniques in a mixture-model environment to leverage the speed and advantages of machine learning. This approach will have a great impact when re-processing large data-sets and data-streams from next generation telescopes, such as the LSST and the E-ELT.

344.14

Naval Observatory Vector Astrometry Software (NOVAS) Version 3.1, Introducing a Python Edition Eric G. Barron¹, G. H. Kaplan¹, J. Bangert¹, J. L. Bartlett¹, W. Puatua¹, W. Harris¹, P. Barrett¹ ¹US Naval Observatory.

Exhibit Hall

The Naval Observatory Vector Astrometry Software (NOVAS) is a source-code library that provides common astrometric quantities and transformations. NOVAS calculations are accurate at the submilliarcsecond level. The library can supply, in one or two subroutine or function calls, the instantaneous celestial position of any star or planet in a variety of coordinate systems. NOVAS also provides access to all of the building blocks that go into such computations. NOVAS Version 3.1 introduces a Python edition alongside the Fortran and C editions. The Python edition uses the computational code from the C edition and, currently, mimics the function calls of the C edition. Future versions will expand the functionality of the Python edition to harness the object-oriented nature of the Python language, and will implement the ability to handle large quantities of objects or observers using the array functionality in NumPy (a third-party scientific package for Python). NOVAS 3.1 also adds a module to transform GCRS vectors to the ITRS; the ITRS to GCRS transformation was already provided in NOVAS 3.0. The module that corrects an ITRS vector for polar motion has been modified to undo that correction upon demand. In the C edition, the ephemeris-access functions have been revised for use on 64-bit systems and for improved performance in general. NOVAS, including documentation, is available from the USNO website (http://www.usno.navy.mil/USNO/astronomical-applications/software-products/novas).

344.15

BetaDrizzle: Astrometry Included

Andrew S. Fruchter¹, W. Hack¹, N. Dencheva¹, M. Droettboom¹

¹STScl.

Exhibit Hall

We present a substantial modification to the MultiDrizzle program which we have temporarily named BetaDrizzle. This program and the procedures around it incorporate all of the astrometric information of an image into the header. Large external calibration files are no longer required. BetaDrizzle can also handle several different astrometric solutions in the same header, allowing the user to transfer between the solutions. Users will also be able to easily pass astrometric header information to each other or back to the archive for use by others. The presence of the full astrometric solution in the header means that users can fit the astrometry of one image to another image, or to an external catalog, without drizzling the image. Precise coordinate information can be extracted directly from the .flt image itself.

344.16

Calibrating Wide Field Channel Imagery for the Post-SM4 Advanced Camera for Surveys Amber Armstrong¹, N. Grogin¹, P. Lim¹, D. Golimowski¹, L. Smith¹

¹Space Telescope Science Institute.

Exhibit Hall

The Wide Field Channel detector of the Advanced Camera for Surveys on board the Hubble Space Telescope was restored to operation during HST Servicing Mission 4 in May 2009. With new control electronics and almost nine years in low Earth orbit, the ACS WFC presents a variety of calibration challenges both old and new. These include mode-dependent bias gradients, bias striping noise, bad columns, cold columns, hot pixels, bad pixels, "scarring," read-out amplifier crosstalk, and substantial charge-transfer inefficiency. Fortunately, most of these detector irregularities are already corrected or flagged by the existing ACS WFC calibration pipeline, designed prior to the WFC failure. However, our close inspection of post-SM4 calibration images, including bias frames, dark exposures, and astronomical reference fields has motivated us to modernize the WFC calibration pipeline so that we may continue to deliver images of the highest possible quality to the HST observer. We provide a quantitative summary of the various post-SM4 WFC image calibration issues, as well as our strategies for addressing them both within the automated calibration pipeline and outside the pipeline as optional stand-alone calibration utilities available to the HST user community.

344.17

Analysis of XMM-Newton Data from Extended Sources and the Diffuse X-ray Background

Steven L. Snowden¹, K. D. Kuntz²

¹NASA's GSFC, ²JHU.

Exhibit Hall

Reduction of X-ray data from extended objects and the diffuse background is a complicated process that requires attention to the details of the instrumental response as well as an understanding of the multiple background components. We present methods and software that we have developed to reduce data from XMM-Newton EPIC (both MOS and PN instruments) imaging observations. The software has now been included in the Science Analysis System (SAS) package available through the XMM-Newton Science Operations Center (SOC).

344.18

Quasi Static Speckle Calibration Using An Integral Field Spectrograph: Extraction Of The Spectrum Of A Faint Companion.

Laurent Pueyo¹, S. Hinkley², J. Crepp², G. Vasisht³, B. R. Oppenheimer⁴, D. Brenner⁴, L. Hillenbrand², L. Roberts³, R. Soummer⁵

¹Johns Hopkins University/ STScI, ²California Institute of Technology, ³Jet Propulsion Laboratory, ⁴American Museum of Natural History, ⁵Space Telescope Science Institute. Exhibit Hall

The contrast floor of current telescopes is set by the light diffracted by the imperfection on the various surfaces of the their optical train. When these errors are very stable, in the case of a space observatory for instance, they can be calibrated and subtracted using reference observations. However, in the case of ground-based telescopes, these so called speckles are time dependent and refined observing scenarios associated with appropriate post-processing techniques need to be developed in order to discriminate real astronomical companions from fiducials due to optical imperfections. In this paper we report recent advances in speckle calibration obtained using the P1640 Integral Field Spectrograph, installed at the Palomar Hale telescope. We present a novel algorithm that combines wavelength diversity and optimized Point Spread Function subtraction in order to detect faint companions lying underneath Adaptive Optics residuals. We show how this method allowed us to increase the dynamic range of our images up to the photometric limit. Then we discuss a spectral calibration method that retrieves the spectrum of this faint companion independently of the gain and bias introduced by the PSF subtraction algorithm. We validate this method and apply it to the characterization of a young binary system.

345 *Intergalactic Medium, QSO Absorption Line Systems* Poster Session *Exhibit Hall*

345.01

Effects of UV Background and Local Stellar Radiation on the H_I Column Density Distribution Kentaro Nagamine¹, J. Choi², H. Yajima³

¹Univ. of Nevada, Las Vegas, ²Univ. of Kentucky, ³Pennsylvania State University. Exhibit Hall

We study the impact of ultra-violet background radiation field (UVB) and the local stellar radiation on the H_I column density distribution $f(N_{HI})$ of damped Lyman-alpha systems (DLAs) and sub-DLAs at z=3 using cosmological smoothed particle hydrodynamics simulations. We find that, in the previous simulations with an optically thin approximation, the UVB was sinking into the H_I cloud too deeply, and therefore we underestimated the $f(N_{HI})$ at 19 < log(N_{HI}) < 21.2 compared to the observations. When the UVB is shut off in the high-density regions with n_{gas} > 6 x 10⁻³ cm⁻³, then we reproduce the observed $f(N_{HI})$ at z=3 very well. We also investigate the effect of local stellar radiation by post-processing our simulation with a radiative transfer code, and find that the local stellar radiation reduces the $f(N_{HI})$ by a factor of ~0.7, which further improves the agreement with the observation. Our results show that the shape of $f(N_{HI})$ is determined primarily by the treatment of UVB, with a weaker effect by the local stellar radiation, and that the optically thin approximation often used in cosmological simulation is inadequate to properly treat the ionization structure of neutral gas in and out of DLAs.

345.02

A Search for Intrinsic HI 21-cm Absorption Toward Compact Radio Sources

Katie Grasha¹, J. Darling¹

¹University of Colorado.

Exhibit Hall

We present a search for intrinsic HI 21 cm and OH 18 cm absorption within the host galaxies of 143 compact radio sources in the redshift range 0.02 < z < 3.8. We use our results on 105 interference-free sources to test two hypotheses: (1) roughly half of compact radio sources show intrinsic 21 cm absorption, and (2) 21 cm absorption is not detected in host galaxies where the active galactic nucleus (AGN) exhibits a high ultraviolet luminosity (greater than 10^{23} W/Hz; Curran et al. 2008). Despite adequate sensitivity to detect nearly any damped Lyman alpha system and despite successful redetection of all previously known absorption line detections. Our observations do not support the high fraction of intrinsic absorption systems in compact radio source hosts found by previous studies at low redshift. They do, however, support the UV luminosity threshold hypothesis proposed by Curran et al. (2008). We attribute the lack of intrinsic HI absorption in our sample to a selection bias favoring UV-luminous AGN, particularly at high redshift, although the detailed physical reason for the UV luminosity effect on HI absorption remains ambiguous.

Curran, S.J. et al. 2008, MNRAS, 391, 765

345.03 The 21cm Forest Katherine J. Mack¹

¹University of Cambridge, United Kingdom.

Exhibit Hall

Future observations of the 21cm forest -- neutral hydrogen absorption against high-redshift radio sources -- will allow us to trace out the structure of the pre-reionization intergalactic medium (IGM), provided bright radio sources can be found at sufficiently high redshift. I will present a calculation of the expected 21cm forest as might be observed in coming years and show how statistical detection techniques could be used to overcome the low signal-to-noise. I will also discuss the trade-off between the availability of large populations of high-redshift background radio sources and the requirement that the IGM be sufficiently neutral for strong absorption.

345.04

Three Dimensional Structure of the Magellanic Bridge Explored by High-Resolution Spectroscopy of Multiple Sightlines.

Paola Rodriguez Hidalgo¹, J. Charlton¹, T. Misawa², P. Richter³, C. Kobulnicky⁴, B. Wakker⁵ ¹The Pennsylvania State University, ²Shinshu university, Japan, ³Institute of Physics and Astronomy, Germany, ⁴Department of Physics & Astronomy, University of Wyoming, ⁵University of Wisconsin-Madison.

Exhibit Hall

The Magellanic Bridge is a physical connection between the Large Magellanic Cloud and the Small Magellanic Cloud. It is known to contain a young stellar population that was probably formed in local molecular clouds. High column density of neutral hydrogen (H I) in the Magellanic Bridge also suggests it could be a local counterpart of Damped Lya (DLA) systems, mysterious H I gas reservoirs at high-z. We carry out an analysis of VLT/UVES spectroscopy of multiple sight-lines of the Magellanic Bridge toward QSOs/AGNs behind it, covering Ca II H, K lines and Na I D1, D2 lines. These measurements are essential to evaluate physical conditions of gas clouds in the Magellanic Bridge along multiple sight-lines derived from the photoionization models. The data provide the unique opportunity to study the three dimensional structure of a DLA analog in our Local Group.

345.05

The MgII Absorption View Through z<1 Galaxies

Nigel Mathes¹, P. Rodriguez-Hidalgo¹, J. Charlton¹, S. Rao², D. Nestor³

¹Penn State University, ²University of Pittsburgh, ³University of California, Los Angeles. Exhibit Hall

We compare the kinematics and absorption properties of a sample of 30 strong MgII absorbers at z<1 to their host galaxy impact parameters and luminosities. The MgII absorption properties are derived from high resolution quasar spectra from the HIRES/Keck and UVES/VLT public archives. The host galaxy properties come from the larger imaging survey of Rao et al. (2010), which has the aim of relating DLA, sub-DLA, and LLS properties to the properties of the host galaxies. That survey yields the result that absorbers with larger neutral hydrogen column densities (i.e. damped Lyman-alpha absorbers) tend to be located at smaller impact parameter than those with smaller neutral hydrogen column densities (i.e. sub-DLA and Lyman limit absorbers). We quantify the MgII absorption properties with: 1) kinematic spread (the optical depth weighted second velocity moment) of the 2796A profile; 2) total velocity range that have detected absorption features). We find that there is significant scatter in the relationships between the MgII absorption properties and the impact parameter and luminosity of the absorbing

galaxy. However, we do find that absorbers with small impact parameters tend to have larger absorbed pixel fractions than those at large impact parameters. We interpret these results based upon the interplay of the various processes responsible for MgII absorption and its kinematics. The lack of strong correlations could be due to contributions to the absorption kinematics from the complex mix of superwinds, high velocity clouds, dwarf galaxy satellites, and to the stochastic nature of galaxy disks.

345.06

Quasar Redshift Determination with a Data-driven Model

Michael Maseda¹, J. Hennawi², D. Hogg³, P. Tsalmantza²

¹Caltech, ²Max-Planck-Institute für Astronomie, Germany, ³NYU. Exhibit Hall

We present a method for determining redshifts of quasars by fitting them with a data-driven model. This model is similar to Principle Component Analysis (PCA), as it uses as much of the information present in the data sample to create a set of basis functions used to iteratively fit the complete set of spectra. We choose to start with the data from the Sloan Digital Sky Survey (SDSS), and thus provide a model of the space of possible quasar spectra in the survey. We show that these redshift determinations are an improvement over those determined by cross-correlation with a fixed quasar template, and that they perform well even when the narrow [O III] lines are outside the spectroscopic window.

345.07

Search for the Very Weakest MgII Absorbers

Therese Jones¹, J. Charlton², P. Rodriguez Hidalgo², A. Narayanan³ ¹UC Berkeley, ²Penn State University, ³University of Wisconsin.

Exhibit Hall

We report on a search for very weak Mg II absorbers in the highest S/N high resolution spectra obtained with the Very Large Telescope (VLT) Ultraviolet and Visual Echelle Spectrograph (UVES). Although the structures selected by weak Mg II absorbers remain unidentified, they select optically thin gas with metallicities 0.5-2 dex higher than the metallicity of DLA absorbers, and are thought to have a variety of origins, from high velocity gas in external galaxies, to interstellar gas clouds expelled from dwarf galaxies and superwinds, and intergalactic star clusters. With a typical 5 sigma detection limit of 0.002Å, an order of magnitude smaller than that of the deepest previous surveys for weak Mg II absorption, we are able to analyze a population of weak Mg II absorbers with small equivalent widths. We consider whether the population of weak Mg II absorbers increases rapidly in this small equivalent width regime, continuing a trend in the increase of the equivalent width distribution of weak ($W_r > 0.02$ Å) absorbers at z~1, which have a dN/dz two times higher than that of Lyman Limit Systems. Such very weak absorbers may be detected via a mix of both narrow (b~3 km/s) single low ionization components and broader (b~6-10 km/s) components. Some of the broader components are likely related to CIV absorbers, while many of the narrow components, detected at the resolution limit of the spectrum, may be associated with unresolved cold clouds whose temperature range extends into the molecular regime. With the broad wavelength coverage of the UVES spectra, we also consider the evolution of these absorbers, from z=0.3-2.4 (at ages 2.8 Gyr-10.3 Gyr).

345.08

Ionic Column Density Measurements Of Low Redshift Metal-Rich IGM Absorbers

Leanne Curtin¹, J. Scott¹, C. W. Danforth²

¹Towson University, ²University of Colorado.

Exhibit Hall

We present a study of 25 z < 0.4 intergalactic absorption systems with detections of three or more metal ions using spectra of 17 quasars from the Far Ultraviolet Spectroscopic Explorer and the E140M mode of

the HST/Space Telescope Imaging Spectrograph.

Previously, we characterized the component structure of the absorption in several ions, O VI, N V, C IV/C III/C II, Si IV/Si III/Si II, S IV/S III/S II, and Fe III/Fe II, and measured the velocity offsets of these ions relative to the Lyman series lines. We found some evidence for multiphase structure. We continue that work here by first expanding our search list to include over 100 ions. We present column density measurements of all the species in these systems, for use in ionization modeling.

345.09

The Physical Nature of the z \sim 0.274 Lyman–Limit System toward PKS1630–377

Joseph Ribaudo¹, N. Lehner¹, J. Howk¹, T. Tripp², J. X. Prochaska³, J. K. Werk³

¹University of Notre Dame, ²University of Massachusetts, ³University of California Santa Cruz. Exhibit Hall

The absorption features seen in the spectra of quasi-stellar objects (QSOs) provide a unique opportunity to probe the galactic and intergalactic regions which intersect the lines of sight (LOS). Understanding the environment of these absorbers allows us to make a connection with physical structures and study the properties and evolution of galaxies, the intergalactic medium (IGM), and the galaxy-IGM interface. We examine a Lyman-limit system (LLS) at z ~ 0.274 along the LOS of the QSO PG1630+377(z_{em} =1.478), using new, high signal to noise data from the Cosmic Origins Spectrograph. The LLS shows strong O VI and C III absorption, but is lacking evidence of low-ion absorption, indicating the absorber is substantially ionized. This result contrasts observations of similar absorption systems such as PKS0405-123 and PKS0312-77, which show clear low-ion absorption. We also investigate the galactic environment surrounding the absorber to identify potential host galaxies using images from the Large Binocular Telescope and spectroscopic redshifts from Keck. We find two galaxies at z ~ 0.275, indicating the absorber is tracing material physically associated with extended galactic regions.

Support for program number HST-GO-11741 was provided by NASA through a grant from the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS5-26555.

345.10

Flux Calibration Of Images Of The Large Magellanic Cloud

Mark A. Bryant¹, S. Points²

¹Southern University, ²AURA CTIO, Chile.

Exhibit Hall

The Magellanic Cloud Emission Line Survey (MCELS) is a survey of two of our nearest neighboring galaxies, the Large and Small Magellanic Clouds (LMC and SMC, respectively). Data has been obtained in the emission-lines of [O III] 5007A, H-alpha 6563A, and [S II] 6724A, as well as green and red continuum filters. These data will allow us to investigate the physical properties of the interstellar medium (ISM) in these galaxies. To this end, there are ~1250 images (250/filter) in a 9degx9deg field toward the LMC. These data have overscan-corrected, trimmed, zero-subtracted, and flat-fielded. This project involves determining astrometric solutions for all fields, sky-subtraction, flux-calibration, continuum subtraction, and mosaicking the data into 1 image per filter.

345.11

Uncovering the Weakest Absorbers in AGN Spectra

Charles Danforth¹, J. T. Stocke¹, J. M. Shull¹, M. Pieri¹, B. Savage², K. France¹, S. Penton¹, B. Keeney¹ ¹Univ. of Colorado, ²Univ. of Wisconsin.

Exhibit Hall

The exquisite far-UV sensitivity of the Cosmic Origins Spectrograph has yielded moderate-resolution AGN spectra of unprecedented quality with signal to noise ratios (S/N) of 50 per resolution element in

some cases. This high data quality allows us to detect some of the weakest (W~10 mÅ) absorption features ever found in far-UV spectra including weak photoionized Ly α forest absorbers at column densities N > 10¹² cm⁻² that may trace significant numbers of baryons in the form of ionized hydrogen, weak broad HI absorbers with b > 40 km/s that potentially trace warm collisionally ionized gas, and weak metal-line counterparts to Ly α absorbers in the intergalactic medium. However, accurately identifying and measuring weak astrophysical absorbers requires detailed knowledge of the spectrograph detectors and the latest in flat-fielding techniques. We present the results of both interactive and automated line searches in several of the highest-quality (S/N=30-50) extragalactic COS datasets taken to date. We catalog weak narrow lines, broad absorption features, and comment on the applicability of these techniques to the larger catalog of COS observations with more modest S/N.

345.12

HST/COS Spectra of Three QSOs that Probe the Extended Gaseous Halo of a Single Galaxy

Brian A. Keeney¹, J. T. Stocke¹, J. L. Rosenberg², C. W. Danforth¹, J. M. Shull¹, B. D. Savage³, J. C. Green¹ ¹Univ. of Colorado, ²George Mason Univ., ³Univ. of Wisconsin.

Exhibit Hall

We present moderate-resolution Cosmic Origins Spectrograph (COS) far-UV spectra of three QSOs that probe the extended gaseous halo of the nearby spiral galaxy ESO 157-G049 (cz = 1673 km/s; L = 0.1 L*) at impact parameters of 53, 66, and 124 kpc. H I Lyman-alpha absorption is detected at the galaxy redshift in the spectra of all three QSOs and metal lines of Si III, Si IV, and C IV are detected in two of the three spectra. No metals are detected in the sight line that probes ESO 157-G049 along its minor axis at an impact parameter of 124 kpc, implying that there is no galactic wind that reaches these radii. Further, no low ions (i.e., C II, Si II) associated with ESO 157-G049 are detected in any of the QSO spectra so its gaseous halo is highly ionized even at radii of ~50 kpc. These spectra allow us to probe the three-dimensional structure of low- and intermediate-ionization gas in nearby galaxy halos for the first time and begin to map the distribution of metals and energy as a function of impact parameter and position angle with respect to the galaxy.

346

Undergraduate Astronomy Education and Research Poster Session *Exhibit Hall*

346.01

Tracking Success in Large Introductory Classes using Technology Thomas H. Robertson $^{\rm 1}$

¹Ball State Univ..

Exhibit Hall

A common problem frequently encountered in large introductory classes is the anonymity experienced by students. An effort is underway at Ball State University to explore the impact of technology on reducing this anonymity and improving student performance and success. In preparation for this study, performance and success measures for students in a previous class have been examined to provide background for construction of a model for formal testing and a control group for comparison of future results. Student performance measures obtained early in the course and final course grades were examined to identify potential early warning indicators that might be used to plan interventions much earlier than the traditional midterm course reports used to alert freshmen at academic risk. Class participation scores were based on data obtained with a personal response system (i>clicker). The scores were scaled to reflect about 80% comprehension and 20% attendance. Homework scores were obtained using the LON-CAPA Course Management System and instructional materials created by the author. Substantial linear correlations exist between 1) Exam 1 Scores after Four Weeks and 2) Raw Class Participation Scores for the First Six Weeks and the Final Course Score. A more modest linear correlation was found between 3) Homework Scores for First Six Weeks and Final Course Score. Of these three measures, only Class Participation Scores identified all students who ultimately received course grades lower than C. Several students scored in the danger zone according to Homework and Class Participation Scores but earned course grades of C or better. It appears that an early warning plan based on Class Participation Scores would permit effective identification of at-risk students early in the course.

346.02

Who is dropping your course?

Alex Storrs¹, C. Ghent¹, R. Labattaglia¹

¹Towson Univ..

Exhibit Hall

We present an analysis of pre and post instruction instruments in a basic astronomy course. This analysis is built on the Light and Spectroscopy Concept Inventory (LSCI, Bardar et al. 2007). In addition to assessing our student's gain in knowledge of this fundamental topic, we have added some demographic questions. While the primary purpose is to compare the gain in knowledge during a semester of instruction to changes in instruction, we also look at the demographics of students who take the pretest but not the posttest. These students are usually excluded from this type of analysis. We look for trends in the demographic information among students who drop the course, and suggest ways to make the course more palatable.

References:

Bardar et al., 2007: "Development and Validation of the Light and Spectroscopy Concept Inventory", Astr. Ed. Rev. **5**(2), 103-113

346.03

A learner centered Student Observation Driven Astronomy (SODA)course

Mark Bottorff¹, S. Doty¹, J. Heaton¹

¹Southwestern Univ..

Exhibit Hall

The non-science major astronomy course, Exploring the Universe, at Southwestern University is now a Student Observation Driven Astronomy (SODA) course. This minimal lecture course emphasizes using student collected observations to infer basic astronomical information about the universe. Observational data is obtained using small telescopes, inexpensive imaging cameras, and reticule eyepieces. The data are collectively analyzed by students in the classroom. In this poster we present the SODA activities that have been successfully carried out in this learner centered course.

346.04

A Writing Assignment For Astr 101 Students Inspired By The "Visions Of The Universe" Exhibit Noella L. D'Cruz¹

¹Joliet Junior College.

Exhibit Hall

The "Visions of the Universe" exhibit was created by the American Library Association, Space Telescope Science Institute and the Smithsonian Astrophysical Observatory to celebrate the International Year of Astronomy. The exhibit consists of 12 posters. Smaller versions of the posters can be downloaded from http://amazing-space.stsci.edu/visions/ for use at institutions that were not part of the exhibit display. We arranged to display these smaller versions at Joliet Junior College.

To encourage ASTR 101 and Life in the Universe students to expand their interest in astronomy via these posters, in Spring 2010 we designed a short essay assignment that counted as one homework. This

assignment involved exploring a poster topic further via the internet. In addition to learning about the topic, students were asked to critique the webpage they chose as their reference, and to recommend whether or not their chosen webpage would be a suitable resource for non-science majors. We will provide details of the assignment, and report on which exhibit topics were most popular, which websites students referred to and which they recommended for introductory astronomy courses.

346.05

Web-based Learning Modules using Research Data

Catherine A. Pilachowski¹, R. Hamper¹, F. Morris¹

¹Indiana University.

Exhibit Hall

Three web-based learning modules for introductory undergraduate astronomy courses are available at Indiana University Bloomington. The NovaSearch module allows students to view images of the core of the Andromeda Galaxy to discover novae and monitor their light curves. The Proper Pair module allows students to examine proper motion and parallax data from Hipparcos to determine if pairs of stars close together on the sky are true binary star systems. A third module, Astronomy in Color, allows students to produce color images using multi-wavelength data. The pedagogical goals of these curriculum materials are to teach that science is a process of discovery, not just a body of knowledge, to increase positive attitudes towards science by engaging students in discovery, and to motivate students towards pursuing STEM careers by giving students an opportunity to develop skills such as critical thinking, teamwork, and task focus that are important in any career path. The learning modules may be accessed at *www.astro.indiana.edu/catyp/rbseu*

The development of these curriculum modules has been funded by the national Science Foundation through grant DUE-0618441.

346.06

Origins Of The Elements - An Educational Web Site

Iranga Samarasingha¹, I. I. Ivans¹

¹University of Utah.

Exhibit Hall

This poster introduces a new and unique web site "ORIGINS OF THE ELEMENTS" to the astronomy and physics communities. The main objective of our site is to provide a useful reference guide to the origins of the elements for researchers, educators and students.

Only a very few of the lightest elements have their origins at the earliest cosmological ages of the Universe, the Big Bang. Most of the elements found on the Earth, and in the rest of the Universe, owe their primary existence to stellar nucleosynthesis, either during the course of the energy generation lifetimes of stars, or in the exploding supernovae of stars at the end of their lives. A by-product of stellar energy generation and exploding supernovae is alchemy -- the ashes of the energy generation contribution of one element is another, more massive element.

Although various reference sources are available to learn about nucleosynthesis, it's a challenging task to uncover appropriate study materials. In this single site, we present both data and recent research results in a concise and attractive structure. Using tables and charts, the material is presented in a multi-level style.

For each of the elements in the periodic table, and for each of the stable isotopes in the chart of the nuclides, the site gives a clear visualization of their corresponding nucleosynthetic origins. As a consequence, the charts afford an insight into the patterns of nucleosynthesis. Moreover, the web site provides the student with an intuition to the relative distributions of those elements. Another important

feature of our site is that users have direct access to the tabulated elemental abundances (both theoretical and observed) of stars and meteorites.

346.07

The NASA/IPAC Teacher Archive Research Program (NITARP) at Pierce College

Carolyn R. Mallory¹, M. Feig¹, N. Mahmud¹, T. Silic¹, L. Rebull², V. Hoette³, C. Johnson⁴, K. McCarron⁵ ¹Pierce College, ²Spitzer Science Center, ³Univ Chicago/Yerkes Observatory, ⁴Breck School, ⁵Oak Park River Forest High School.

Exhibit Hall

Our team from Pierce Community College, Woodland Hills, CA, participated in the NASA/IPAC Teacher Archive Research Program (NITARP) this past year (2010). (NITARP is described in another poster, Rebull et al.) Our team worked with archival Spitzer, 2MASS, and optical data to look for young stars in CG4, part of the Gum Nebula; our scientific results are described in a companion poster, Johnson et al. In this poster, we describe more about what we learned and how we incorporated our NITARP experiences into the Pierce College environment. Students developed critical thinking skills and an ability to organize their data analysis and develop a mental "big picture" of what is going on in the CG4 region. The NITARP program is one of several "Active Learning" programs going on at Pierce, and the other programs are briefly summarized in this poster as well. This program was made possible through the NASA/IPAC Teacher Archive Research Project (NITARP) and was funded by NASA Astrophysics Data Program and Archive Outreach funds.

346.08

A Simple Device to Measure the Altitude of the Sun Windsor A. Morgan, ${\rm Jr.}^1$

¹Dickinson College.

Exhibit Hall

The changing altitude of the Sun (either over the course of a day or over longer periods) is a phenomenon that students generally do not appreciate. However, the altitude of the Sun affects many areas in disciplines as diverse as astronomy, meteorology, navigation, or horology, such as the basis for seasons, determination of latitude and longitude, or the determination of local apparent noon. Being familiar with the motion of the Sun is important for students' understanding these different topics. I describe here a quadrant that is portable, reliable, and can be easily made in a technician's shop. I discuss possible uses for the quadrant in introductory science classes.

346.09

A Tool For Exploring Spectral Energy Distributions in the Classroom

Darryl Stanford¹, S. Seebode², D. Drumheller¹, S. B. Howell³, D. W. Hoard⁴ ¹College Of San Mateo, ²San Mateo High School, ³NOAO, ⁴Spitzer Science Center. Exhibit Hall

The calculation of spectral type, temperature, radius and distance is often the first step in the study of stars and stellar systems. Spectral energy distributions or SEDs are of paramount importance in the determination of these quantities. We have created an innovative tool that enables high school and college physics and astronomy instructors and their students, to evaluate these parameters. This tool includes templates of main sequence stars with spectral types from O5 to M5 and associated lesson plans. Instructors can use it in a classroom setting and design lab exercises around it. Students can use it for research, determining stellar radii, distances, as well as cluster membership of stellar samples. More complex, multi-component SEDs can be used to investigate stellar systems, with dust disks, as well as, the dusty nuclei of starburst galaxies.

The tool is in google documents format, easily downloadable and modifiable by interested parties, and

will be accessible on the College of San Mateo astronomy website (http://gocsm.net/astronomy/), Teachers and students can add template data for other spectral types and luminosity classes, for their own projects. This study is part of the NASA/IPAC Teacher Archive Research Project (NITARP).

346.10

An Inexpensive, Table-top Set-up For Labs On Aperture Synthesis

Jonathan M. Marr¹, A. E. E. Rogers², V. Fish², M. M. Needles²

¹Union College, ²MIT Haystack Observatory.

Exhibit Hall

Atlhough the radio astronomical technique of aperture synthesis (using an array of interferometers) has been involved in significant contributions to the study of the Universe, it is almost always excluded from an undergraduate curriculum in physics and astronomy because of the complexity of the math involved. As a result astronomy students generally do not understand how instruments like the VLA actually work. We present here an inexpensive (<\$500) table-top set-up which can be used to provide students with hands-on experience in the fundamentals of aperture synthesis. We have developed a set of labs which students can easily perform to obtain an intuitive sense of how combining the signals from an array of antennas reveals information about the structure of the radio source and how high-resolution radio maps can be obtained from this process. Although a thorough mathematical explanation of the process is helpful for advanced students, these labs can be completed without the mathematical lectures and still impart a general conceptual understanding to the lower level students. This work was funded by grants from the National Science Foundation.

346.11

The Northwest Indiana Robotic Telescope

Shawn D. Slavin¹, A. W. Rengstorf¹, J. C. Aros¹, W. B. Segally¹

¹Purdue University Calumet.

Exhibit Hall

The Northwest Indiana Robotic (NIRo) Telescope is a remote, automated observing facility recently built by Purdue University Calumet (PUC) at a site in Lowell, IN, approximately 30 miles from the PUC campus. The recently dedicated observatory will be used for broadband and narrowband optical observations by PUC students and faculty, as well as pre-college students through the implementation of standardsbased, middle-school modules developed by PUC astronomers and education faculty. The NIRo observatory and its web portal are the central technical elements of a project to improve astronomy education at Purdue Calumet and, more broadly, to improve science education in middle schools of the surrounding region.

The NIRo Telescope is a 0.5-meter (20-inch) Ritchey-Chrétien design on a Paramount ME robotic mount, featuring a seven-position filter wheel (UBVRI, H α , Clear), Peltier (thermoelectrically) cooled CCD camera with 3056 x 3056, square, 12 μ m pixels, and off-axis guiding. It provides a coma-free imaging field of 0.5 degrees square, with a plate scale of 0.6 arcseconds per pixel. The observatory has a wireless internet connection, local weather station which publishes data to an internet weather site, and a suite of CCTV security cameras on an IP-based, networked video server. Control of power to every piece of instrumentation is maintained via internet-accessible power distribution units.

The telescope can be controlled on-site, or off-site in an attended fashion via an internet connection, but will be used primarily in an unattended mode of automated observation, where queued observations will be scheduled daily from a database of requests. Completed observational data from queued operation will be stored on a campus-based server, which also runs the web portal and observation database.

Partial support for this work was provided by the National Science Foundation's Course, Curriculum, and Laboratory Improvement (CCLI) program under Award No. 0736592.

346.12

Education and Outreach with the Northwest Indiana Robotic Telescope

Adam W. Rengstorf¹, S. D. Slavin¹

¹Purdue University Calumet.

Exhibit Hall

The Northwest Indiana Robotic (NIRo) Telescope is being used to completely revise the introductory astronomy laboratory experiments at Purdue University Calumet (PUC). The NIRo telescope is a new 20-inch RC telescope. It was dedicated in Aug 2010, is designed to be operated remotely &/or robotically, and is located 30 miles south of PUC's campus in rural Lake county, IN.

A suite of laboratory experiments is being developed and piloted during the 2010-2011 academic year. Lab experiments will progress from introductions to instruments and software, through simple data visualization and analysis, to developing and submitting an observing plan to complete multi-week laboratories. Experiments for both the solar system course and the stars & galaxies are being developed. Students in the solar system course will request and analyze images for such experiments as recreating Aristarchus' relative size & distance calculations, establishing an observing strategy to monitor the Galilean satellites & determine Jupiter's mass, an ongoing 'asteroid hunt', Martian retrograde motion, and Venusian phases. The stars & galaxies course will complete labs on galaxy morphology, eclipsing binaries, building an HR-diagram, cluster aging, and distances to Cepheid variables.

The main outreach component is the development of a primary education program. In conjunction with the PUC School of Education and area middle-school science teachers, we are in the process of identifying the subset of laboratory ideas best suited to the State of Indiana Earth & Space Science teaching standards from grades 6 - 8. These laboratories are being developed into finished data products, curricula, and learning modules appropriate for the middle school classroom. The middle school classroom will be able to request observations and retrieve reduced images via an internet portal, currently in development.

This project has been funded by NSF award #DUE-0736592.

346.13

Astronomy Education and Research With Digital Viewing: Forming a New Network of Small Observatories

Arthur Bogard¹, T. S. Hamilton¹

¹Shawnee State University.

Exhibit Hall

Small observatories face two major hindrances in teaching astronomy to students: weather and getting students to recognize what they're seeing. The normal astronomy class use of a single telescope with an eyepiece is restricted to good skies, and it allows only one viewer at a time.

Since astronomy labs meet at regular times, bad weather can mean the loss of an entire week. As for the second problem, students often have difficulties recognizing what they are seeing through an eyepiece, and the instructor cannot point out the target's features. Commercial multimedia resources, although structured and easy to explain to students, do not give students the same level of interactivity. A professor cannot improvise a new target nor can he adjust the image to view different features of an object.

Luckily, advancements in technology provide solutions for both of these limitations without breaking the bank.

Astronomical video cameras can automatically stack, align, and integrate still frames, providing

instructors with the ability to explain things to groups of students in real time under actual seeing conditions. Using Shawnee State University's Mallincam on an 8" Cassegrain, our students are now able to understand and classify both planetary and deep sky objects better than they can through an eyepiece.

To address the problems with weather, SSU proposes forming a network among existing small observatories. With inexpensive software and cameras, telescopes can be aligned and operated over the web, and with reciprocal viewing agreements, users who are clouded out could view from another location. By partnering with institutions in the eastern hemisphere, even daytime viewing would be possible. Not only will this network aid in instruction, but the common user interface will make student research projects much easier.

346.14

The Summer Undergraduate Research Internship Program at the Pisgah Astronomical Research Institute

Michael W. Castelaz¹, J. Cline¹, C. Whitworth¹, D. Clavier¹

¹Pisgah Astronomical Research Inst..

Exhibit Hall

Pisgah Astronomical Research Institute (PARI) offers summer undergraduate research internships. PARI has received support for the internships from the NC Space Grant Consortium, NSF awards for public science education, private donations, private foundations, and through a collaboration with the Pisgah Astronomical Research and Education Center of the University of North Carolina - Asheville. The internship program began in 2001 with 4 students. This year 9 funded students participated in 2010. Mentors for the interns include PARI's Directors of Science, Education, and Information Technology and visiting faculty who are members of the PARI Research Affiliate Faculty program. Students work with mentors on radio and optical astronomy research, electrical engineering for robotic control of instruments, software development for instrument control and applets for citizen science projects, and science education by developing curricula and multimedia and teaching high school students in summer programs at PARI. At the end of the summer interns write a paper about their research which is published in the PARI Summer Student Proceedings. Several of the students have presented their results at AAS Meetings. We will present a summary of specific research conducted by the students with their mentors, the logistics for hosting the PARI undergraduate internship program, and plans for growth based on the impact of an NSF supported renovation to the Research Building on the PARI campus.

347

Gravitational Lenses and Gravitational Waves Poster Session *Exhibit Hall*

347.01

SBAS: The Sloan Bright Arcs Survey

Huan Lin¹, S. Allam¹, E. Buckley-Geer¹, H. T. Diehl¹, J. Frieman¹, J. Kubo¹, D. Tucker¹, M. Wiesner², Sloan Bright Arcs Survey Team

¹Fermi Nat'l Accelerator Lab., ²Nothern Illinois University.

Exhibit Hall

We are carrying out the Sloan Bright Arcs Survey (SBAS), an ongoing systematic search for bright, strongly-lensed, high-redshift galaxies in samples of SDSS luminous red galaxies, clusters, and interacting/merging galaxy pairs. So far we have spectroscopically confirmed 20 lensing systems, with source galaxy redshifts z = 0.4 - 2.9, and 10 of these are among the brightest known z > 1.8 lensed galaxies. Here we will describe our search program and our sample, as well as our results on lens system

modeling and source galaxy properties, derived from our optical and IR follow-up observations using ground- and space-based telescopes, including APO, Mayall, WIYN, Gemini, and HST.

347.02

Clusters and Lenses: Ten Galaxy Clusters Exhibiting Strong Lensing Found in the Sloan Digital Sky Survey

Matthew P. Wiesner¹, H. Lin², E. Buckley-Geer², J. Annis², S. Allam², J. Kubo², H. T. Diehl², D. Tucker², D. Kubik²

¹Northern Illinois University, ²Fermi National Accelerator Laboratory. Exhibit Hall

The Sloan Bright Arcs Survey (SBAS) at Fermilab has discovered and studied instances of strong gravitational lensing using data from the Sloan Digital Sky Survey. As part of this survey, we took images at the WIYN telescope at Kitt Peak National Observatory of ten strong gravitational lenses discovered by the SBAS; these lenses are all associated with galaxy clusters. Using these data, we have sought to characterize the properties of the lensing clusters. We present our findings of values of mass and richness for the galaxy clusters and our initial findings for the Einstein radii and enclosed masses of the lenses themselves. We also present results corroborating previous groups' findings that the ACDM model may underestimate Einstein radii when predicting them based on cluster masses. Our data set includes lower mass clusters than those considered in previous studies.

347.03

WFC3 and WFPC2 Follow Up of Strong Gravitational Lenses

Sahar S. Allam¹, H. Lin¹, D. Tucker¹, H. Diehl¹, E. Buckley-Geer¹, J. Frieman¹, J. Kubo¹, Sloan Bright Arcs Survey Team

¹Fermilab.

Exhibit Hall

We used the HST WFC3 and WFPC2 instruments to follow up a sample of strong gravitational lenses that probe the group-mass environment. This sample is derived almost exclusively from SDSS data, and has been confirmed via follow-up spectroscopy and imaging on the 3.5 m telescope at the Apache Point Observatory.

We present new lens reconstruction mass models based on HST images, and we discuss the mass-tolight ratio of these systems.

347.04

Analyzing the Flux Anomalies of the Large-separation Lensed Quasar SDSS J1029+2623 Rachael Kratzer¹, G. T. Richards¹, D. M. Goldberg¹, M. Oguri², C. S. Kochanek³, J. A. Hodge⁴, R. H. Becker⁴, N. Inada⁵

¹Drexel University, ²National Astronomical Observatory of Japan, Japan, ³The Ohio State University, ⁴University of California at Davis, ⁵University of Tokyo, Japan.

Exhibit Hall

Using a high resolution radio image, we successfully resolve the two fold image components B and C of the quasar lens system SDSS J1029+2623. The flux anomalies associated with these two components in the optical regime persist, albeit less strongly, in our radio observations, suggesting that the cluster must be modeled by something more than a single central potential. We argue that placing substructure close to one of the components can account for a flux anomaly with negligible changes in the component positions. Our best fit model has a substructure mass of ~10⁸ solar masses up to the mass-sheet degeneracy, located roughly 0.1 arcsecs West and 0.1 arcsecs North of component B. We demonstrate that a positional offset between the centers of the source components can explain the differences between the optical and radio flux ratios.

347.05

Size, Luminosity and Stellar Mass of Compact Lensed Galaxies at Intermediate Redshift Elisabeth R. Newton¹, P. J. Marshall², T. Treu³, SLACS Collaboration

¹Harvard University, ²Kavli Institute for Particle Astrophysics and Cosmology, ³University of California, Santa Barbara.

Exhibit Hall

We exploit the strong lensing effect to explore the properties of intrinsically faint and compact galaxies at intermediate redshift, at the highest possible resolution at optical wavelengths. We model 46 strongly-lensed emission line galaxies discovered by the Sloan Lens ACS (SLACS) Survey, using KLENS, a quick and robust new code which we test extensively on real and synthetic non-lensed galaxies, and also on simulated lenses. We are able to infer their size, luminosity, and stellar mass using stellar population synthesis models. Modeling the SLACS sources reveals a population of galaxies with colors and Sersic indices (median $n \sim 1$) consistent with the objects detected in the field with HST in the GEMS survey, but that are (typically) ~ 2 magnitudes fainter and ~ 5 times smaller in apparent size. The closest analog to the population we see are the ultra-compact emission line galaxies identified by HST grism surveys. The lowest mass galaxies in our sample are comparable in stellar mass to the brightest Milky Way satellites ($10^7 M_{\odot}$) and have well-determined half light radii of 0.05 arcsec (≈ 0.3 kpc). TT and ERN acknowledge support from the NSF through CAREER award NSF-0642621, and from the Packard Foundation through a Packard Research Fellowship. PJM is grateful to the TABASGO and Kavli

foundations for support in the form of two research fellowships.

347.06

New Methods for Identifying Nearby Gravitational Lenses in All-Sky Surveys Samuel McCandlish¹, R. Di Stefano²

¹Brandeis University, ²Harvard-Smithsonian Center for Astrophysics. Exhibit Hall

All-sky catalogs provide a wealth of information about gravitational lensing events that has not yet been utilized. We present a method for matching lensing events to catalogs and finding the probability that the association is genuine. Given a likely candidate for the lens object associated with an event, it is possible to break the inherent degeneracy in microlensing and estimate the mass of the lens, depending on its distance. Eight percent of microlensing events have matches in the 2MASS catalog, and there are many more matches in catalogs that cover other wave bands. In addition to detecting the associated lens or source, it is possible that the cataloged object is a companion or host to the actual lens. This opens up the possibility of finding dark nearby lenses, such as stellar remnants or planets that are associated with cataloged objects. We propose various methods for determining which events are most likely to be caused by nearby lenses, and apply them to our matches. We present some interesting matched objects and the results of observations of those objects.

This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 0754568 and by the Smithsonian Institution.

347.07

The Laser Interferometer Space Antenna (LISA)

Thomas Allen Prince¹, LISA International Science Team

¹Caltech/JPL.

Exhibit Hall

LISA is a joint NASA/ESA space mission designed to measure gravitational waves in the band from 0.1 mHz to 0.1 Hz, a band that is richly populated by strong sources of gravitational waves. Signals will come from a wide range of sources: massive black holes merging in galaxies; compact objects captured by

massive black holes; ultra-compact Galactic binaries; and possibly other sources such as relics of the Big Bang. These sources convey detailed information addressing a wide range of physics and astrophysics: the history of galaxies and black holes in the universe; general relativity; measurements of luminosity distances; the physics of dense matter and stellar remnants; and possibly new physics associated with events in the very early universe. The LISA mission uses laser metrology between three spacecraft separated by 5 million km to detect gravitational wave sources with very high sensitivity. We will describe the LISA mission and summarize its current status, including technology development and the upcoming LISA Pathfinder mission.

347.08

The Promises And Challenges Of Lisa Science

Michele Vallisneri¹, U.S. LISA Mission Science Office

¹Jet Propulsion Laboratory.

Exhibit Hall

The planned space-based observatory LISA will target gravitational waves of frequency between 0.1 mHz and 1 Hz. This band is populated by thousands of detectable astrophysical sources, which will enable many exciting investigations: exploring hierarchical galaxy formation scenarios, sampling the strong-field regime of general-relativistic dynamics, taking a census of Galactic compact binaries, characterizing the nature of the massive objects at galactic centers, and much more. In the last decade, the LISA community has achieved many proofs of principle that we will be able to extract the best possible science from the LISA data; in the remaining years before LISA is launched we must now work toward mature and robust analysis tools, making the best use of the experience of ground-based gravitational-wave astronomy, and of the advances in astronomical surveys and databases.

347.09

Are Deep JWST Surveys of the First Light Epoch Limited by Instrumental, Natural, or "Gravitational" Confusion?

Rogier A. Windhorst¹, J. S. B. Wyithe², H. Yan³, S. Mao⁴

¹ASU, ²Univ. of Melbourne, Australia, ³Ohio State Univ., ⁴Jodrell Bank, Univ. of Manchester, United Kingdom.

Exhibit Hall

We review the instrumental and natural confusion limits for the 6.5m James Webb Space Telescope (JWST), which apply to mostly unresolved or mostly resolved objects, resp. For ultradeep JWST surveys with ~0.08" FWHM resolution, the natural confusion limit may become more important for the definition of faint object samples than the survey surface brightness (SB) limit. This effect may already be visible in the deepest HUDF images for AB>25 mag. This does, however, not mean that the deepest JWST samples will be fundamentally limited by natural confusion. Instead, from hierarchical simulations we argue that for AB>28 mag, faint objects seen by JWST are likely mostly unresolved at 0.08" FWHM. For these objects, instrumental confusion doesn't set in until AB>33.5 mag, a limit which even JWST will not reach. Does this therefore mean that the confusion limit is irrelevant for JWST?

We show that gravitational lensing will lead to a correlation between the sky positions of high redshift candidates and bright foreground galaxies, and present evidence for this correlation among a sample tentatively identified at z~10.6. By extrapolating the evolution of the galaxy LF-slope and amplitude to z>8, we suggest that gravitational lensing may dominate the observed properties of galaxies at z>10 discovered by JWST. The observed surface density of galaxies at z~12-15 will likely be boosted by an order of magnitude, and most z>12-15 galaxies may well be part of a multiply-imaged system, located less than 1 arc-second from a brighter foreground galaxy.

This means that deep JWST surveys of the First Light epoch at z>10 may be limited by "gravitational"

confusion, where a good part of the First Light "forest" may be gravitationally amplified by the foreground galaxy "trees". Lensing bias will therefore need to be carefully considered for First Light studies with JWST.

348 *Catalogs* Poster Session *Exhibit Hall*

348.01

New Stars In The Solar Neighborhood (d<15 Parsecs) From The Southern Sky Extension Of The Superblink Survey

Faith Pilacik¹, S. Lepine²

¹Clemson University, ²American Museum of Natural History. Exhibit Hall

The SUPERBLINK survey is currently expanding the census of high proper motion stars. After mapping the entire Northern sky for stars down to proper motion of 40 mas/yr, the survey has turned to the South celestial hemisphere, with the same goal to provide a reliable catalog of carefully verified high proper motions stars. We have sought to identify previously unknown stars within 15 parsecs of the Sun, among stars with proper motions between 0.04 and 0.15 seconds of arc per year and in the declination range between 0 and -20 degrees. Currently, out of 187 stars, 15 new stars have been identified. Photometric distances were calculated from infrared and optical colors and magnitudes (from the 2MASS and USNO-B catalogs), and infrared color cuts were used to eliminate background giants. A list of the new Solar neighbors is presented.

348.02

The At20g and the Search For Young Galaxies Paul Hancock $^{\!\!1}$

¹Sydney Institute for Astronomy, Australia. Exhibit Hall

The AT2OG survey is a wide area, high frequency, sensitive survey of the southern hemisphere. In this poster I describe a catalog that was created from the scanning survey data, that is complementary to the main, follow-up survey catalog. The complimentary catalog is complete to a lower flux limit but does so with the inclusion of more false positive sources. Such a catalog is more suited to CMB projects such as PLANCK or the SPT, where false positives are less detrimental than incompleteness. A supplement to the AT2OG catalog is also included.

348.03

NIST Calibrations of Spectrophotometric Standard Stars

Claire Cramer¹, S. W. Brown¹, K. R. Lykke¹, A. W. Smith¹, J. T. Woodward¹, E. E. Falco², C. W. Stubbs³, J. T. McGraw⁴, P. C. Zimmer⁴

¹NIST, ²Harvard-Smithsonian Center for Astrophysics, ³Harvard University, ⁴University of New Mexico. Exhibit Hall

The National Institute of Standards and Technology (NIST) has begun a program to create a catalog of stars with SI-traceable spectral energy distributions known at the sub-percent level. Here, we outline our procedure to make ground-based observations of stellar spectra that are both accurate and precise. We describe the calibration of these spectra with NIST-traceable sources and detectors, and summarize our plans to make concurrent measurements of atmospheric transmittance.

348.04 Bright Star Astrometry Through The Dark Robert T. Zavala¹

¹US Naval Observatory.

Exhibit Hall

The Navy Prototype Optical Interferometer (NPOI) is completing a wide-angle astrometric catalog of bright (v<= 5 mag) stars with a goal of absolute positions good to 15 mas. Narrow-angle astrometric observations with a single-mirror telescope of these bright stars against a fainter (v> 12) reference catalog will be used as one assessment of the accuracy of the interferometric catalog. I will present observations of bright radio stars seen through a 9-magnitude neutral density spot and compare these observed positions against the current epoch predicted HIPPARCOS positions. These radio star observations, and some observations of extragalactic objects, form our initial check of our narrow-angle astrometry. Other uses of these observations include relative astrometry to detect orbital perturbations from companions to verify duplicity or improve previously determined orbits.

348.05

Applications of CaH Photometry to Red Stars Thomas H. Robertson¹

¹Ball State Univ..

Exhibit Hall

A photometric system using Kron-Cousins R and I magnitudes with an intermediate-band CaH filter has been in use for a number of years. This system was designed to produce luminosity classes and photometric parallaxes for red dwarf stars with R-I > 0.7. Observations have been made on three different telescopes equipped with four different CCD cameras, two different CaH filters and three different Kron-Cousins filter sets. The system has remained consistent and provides for relatively easy transformation from one set in instrumental/standard magnitudes to another. Data collected using these various hardware systems have been transformed to a uniform system and the numerical parameters for luminosity classification are provided.

349

Astrobiology & Laboratory Astrophysics Poster Session *Exhibit Hall*

349.01

Gamma-Ray Bursts and Marine Primary Producers

Brian Thomas¹, P. J. Neale²

¹Washburn Univ., ²Smithsonian Environmental Research Center. Exhibit Hall

Gamma-ray bursts (GRB) have been recognized as a potential threat to life on Earth, primarily through long-term depletion of stratospheric ozone, leading to greatly increased solar ultraviolet (UV) irradiance at the surface. It has been suggested that a GRB may have initiated the late Ordovician mass extinction one of the "big five" known extinctions. Past efforts by our group to estimate the biological impact of a GRB have used a simplified Beer-Lambert calculation with an ozone column density to estimate surface UV irradiance. Biological damage was then computed by combining the irradiance with a biological weighting function (BWF) for DNA damage.

We are currently engaged in a project to greatly increase the accuracy of these estimates, with a focus on the impact on primary producers in the Earth's oceans. These organisms make up the base of the marine food web and produce half the world's oxygen. Our approach features full radiative transfer modeling to determine surface UV irradiance, combined with newly measured biological weighting functions for some of the most abundant marine primary producers. Here, we report on preliminary results of this study, including computed spectral irradiance at the surface and in ocean water under conditions following a GRB, along with the impact on primary productivity as computed using preliminary BWF results.

This work is supported by NASA's Astrobiology: Exobiology and Evolutionary Biology program, grant #NNX09AM85G.

349.02

Detailed Temperature Map of the Taurus Molecular Cloud

Andrew Battisti¹, M. Jones², G. Langston³

¹University of Massachusetts at Amherst, ²University of Wisconsin at Madison, ³NRAO. Exhibit Hall

The Taurus Molecular Cloud (TMC) provides us with a rich environment to study astrochemistry. We used data taken with the K Band Focal Plane Array (KFPA) on the Green Bank Telescope (GBT) to measure ammonia (NH₃) (1-1) and (2-2) lines to produce a detailed temperature map of the cloud. The NH₃ (2-2) line was below the noise level of the measurement and so we present only an upper limit temperature map. Much longer exposures of the cloud will be required to reveal the (2-2) line because of its extremely low temperature. We also created a procedure to detect linear molecules, such as the cyanopolynnes HC₁₁N and HC₁₃N, whose emission behavior is dependent on a rotational constant and a quartic centrifugal distortion constant. This procedure can scan over a range of values for these constants and would sum up all the regions in the spectra (i.e. 1-1, 2-2, etc.) in velocity space where the emissions lines would be and select out cases whose signal would add up to give a SNR greater than 3. This project used archived GBT data that had been combined to create much greater signal to noise ratio.

349.03

Seeding of Life on Moons of the Outer Planets

Rachel Worth¹, S. Sigurdsson¹, C. House¹

¹*The Pennsylvania State University.*

Exhibit Hall

We explore the possibility that life on the potentially habitable moons in the outer Solar System could have been seeded by transfer of meteorite ejecta from Earth or Mars. It has been shown that bacterial spores can remain viable for some time in the vacuum of space, and it is hypothesized that if embedded in rock, they may survive long enough to reach other parts of the Solar System through orbital perturbations. We use numerical n-body simulations to study the ejection of low mass bodies from the inner planets. We follow the orbits of the ejecta for long times to determine the probability that they may arrive at, and impact, the outer moons most interesting from a habitability standpoint, such as Europa.

349.04

Earth as an Extrasolar Planet: Comparing Polar and Equatorial Views of Modern Day and Snowball Earth

Aomawa Shields¹, V. S. Meadows¹, T. D. Robinson¹, D. Crisp², D. Deming³, M. F. A'Hearn⁴, D. Charbonneau⁵, T. A. Livengood³, S. Seager⁶, R. K. Barry³, T. Hearty³, T. Hewagama⁴, C. M. Lisse⁷, L. McFadden⁴, D. D. Wellnitz⁴, EPOXI Earthling Team

¹University of Washington, ²Jet Propulsion Laboratory, ³Goddard Space Flight Center, ⁴University of Maryland, ⁵Harvard-Smithsonian Center for Astrophysics, ⁶Massachusetts Institute of Technology, ⁷Johns Hopkins University Applied Physics Laboratory.

Exhibit Hall

In 2008 and 2009, the EPOXI Discovery Mission of Opportunity re-used the Deep Impact flyby spacecraft to obtain observations of the distant Earth. These spatially- and temporally-resolved visible photometric and moderate-resolution near-infrared spectroscopic observations were taken from vantage points above the Earth's Equator, and the North and South Poles. We have used the NASA Astrobiology Institute's Virtual Planet Laboratory 3-D line-by-line, multiple-scattering Earth model to simulate light curves and spectra for comparison with the EPOXI data. We used this data/model comparison to validate the Earth model for the polar regions, and to explore detectable differences in light curve amplitude, color, atmospheric effects, surface temperature and compositional differences between the poles and the equator. We explore observational differences between a planet that is covered in clouds, and one that is ice-covered, through analysis of multi-wavelength variations in time-averaged light curve amplitude. Although the equatorial view of a Snowball Earth has a large ice surface fraction, as does a modern-day Earth that is viewed from above the pole of the planet, there are discernible differences in globally-averaged surface area between the two planetary conditions, as expressed by variations in light-curve amplitude over a 24-hour rotation period. We are able to quantify the amount of radiation that various surface types contribute to the overall measured intensity of an Earth-like planetary surface as a function of illumination geometry. This has implications for future exoplanet missions, which expect to identify Earth-like planets at different evolutionary phases and viewing geometries. This work was made possible by funding from the Virtual Planetary Laboratory, a NASA Astrobiology Institute Lead Team.

349.05

New Optical Constants for Graphite and Iron Adrian Corman¹, A. Hofmeister¹

¹Washington University in St. Louis.

Exhibit Hall

Radiative transfer models require accurate optical properties of the materials present in the simulation. However, many commonly used sets of optical properties are decades old, obtained using instruments of lower resolution to what is possible today. Additionally, if one requires these optical properties over a large range (such as UV-VIS to mid-IR), it is necessary to combine several different data sets, each taken using different instruments and samples. This can make it difficult to combine these different data sets in a consistent manner; there are also some inconsistencies between different data sets even over the same range. Using reflectance measurements calibrated against a standard, we have obtained optical properties for graphite and iron in a range extending from the UV-VIS to the mid-IR at ambient temperature. We used only two instruments to cover this range, allowing us to more easily combine data sets; also, the same samples were used for the entire range, allowing us to eliminate some of the uncertainties in previous measurements. Data acquisition at lower frequencies and temperatures are planned.

349.06 Transition Probabilities of Gd I

Katherine Bilty¹, J. E. Lawler², E. A. Den Hartog²

¹University of Wisconsin -Eau Claire, ²University of Wisconsin.

Exhibit Hall

Rare earth transition probabilities are needed within the astrophysics community to determine rare earth abundances in stellar photospheres. The current work is part an on-going study of rare earth element neutrals. Transition probabilities are determined by combining radiative lifetimes measured using time-resolved laser-induced fluorescence on a slow atom beam with branching fractions measured from high resolution Fourier transform spectra. Neutral rare earth transition probabilities will be helpful in improving abundances in cool stars in which a significant fraction of rare earths are neutral. Transition probabilities are also needed for research and development in the lighting industry. Rare earths have rich spectra containing 100's to 1000's of transitions throughout the visible and near UV. This makes rare earths valuable additives in Metal Halide - High Intensity Discharge (MH-HID) lamps, giving them a pleasing white light with good color rendering.

This poster presents the work done on neutral gadolinium. We will report radiative lifetimes for 135 levels and transition probabilities for upwards of 1500 lines of Gd I. The lifetimes are reported to $\pm 5\%$ and the transition probabilities range from 5% for strong lines to 25% for weak lines.

This work is supported by the National Science Foundation under grant CTS 0613277 and the National Science Foundation's REU program through NSF Award AST-1004881.

349.07

Effects Of Light Pollution On The Movements Of Leptonycteris Curasoae Yerbabuenae In The Tucson Area

Daniel Barringer¹, C. Walker²

¹Union College, ²National Optical Astronomy Observatory.

Exhibit Hall

We used data from the GLOBE at Night project and telemetry tracking data of lesser long-nosed bats obtained by the Arizona Game and Fish Department to study the effects of light pollution on the flight paths of the bats between their day roosts and night foraging areas around the city of Tucson, AZ. With the visual limiting magnitude data from GLOBE at Night, we ran a compositional analysis with respect to the bats' flight paths to determine whether the bats were selecting for or against flight through regions of particular night sky brightness levels. We found that the bats selected for the regions in which the limiting sky magnitudes fell between the ranges of 2.8-3.0 to 3.6-3.8 and 4.4-4.6 to 5.0-5.2, suggesting that the lesser long-nosed bat can tolerate a fair degree of urbanization. We also compared this result to contour maps created with digital Sky Quality Meter data. In this presentation, we present the results from our compositional analysis with respect to the habits of the lesser long-nosed bat. For more information, please visit www.globeatnight.org.

Wednesday, January 12, 2011, 10:00 AM - 11:30 AM 301 *Early Results from the Wide-field Infrared Survey Explorer* Special Session *Ballroom 6B*

301.01

The Wide-field Infrared Survey Explorer Edward L. Wright¹

¹UC, Los Angeles. 10:00 AM - 10:12 AM Ballroom 6B

The Wide-field Infrared Survey Explorer (WISE) finished its first pass over the sky in 17 July 2010, and surveyed 12 percent of the sky a second time before the secondary hydrogen tank was exhausted. The 22 micron band saturated shortly thereafter. The second pass continues with three bands as of this writing, and has reobserved 28 percent of the sky six months after the first pass. WISE has found hundreds of very cold brown dwarf candidates, and hundreds candidate hyper-luminous infrared galaxies. Over 166 objects discovered by WISE have been discussed in Minor Planet Electronic Circulars. WISE has found more than 115 Near Earth Asteroids including at least 8 larger than 1 km diameter. The first data release from WISE will be a preliminary release of at least 55 percent of the sky in April, 2011.

301.02

Data Processing, Distribution and Product Characteristics for the WISE Preliminary Data Release Roc M. Cutri¹, IPAC/WISE Science Data Center Team

¹Caltech, IPAC. 10:12 AM - 10:24 AM

Ballroom 6B

The Wide-Field Infrared Survey Explorer (WISE) began its digital imaging survey of the sky in the 3.4, 4.6, 12 and 22 micron bands in January 2010. WISE completed its first complete sky coverage in July and will continue to survey until its cryogens are exhausted later this year. A preliminary Image Atlas in the four WISE bands and a corresponding Source Catalog containing accurate positions and mid-infrared photometry that cover the first 55% of the sky surveyed will be released in April 2011. The Infrared Processing and Analysis Center, California Institute of Technology is the WISE Science Data Center (WSDC) and is responsible for processing, archiving and distribution of WISE science data products. We describe the processing system that converts the raw science and engineering data into calibrated Atlas Images and Source Catalog entries, validates and archives these products, and enables access to them by the community. We also describe the general properties of the Preliminary Release data products including areal coverage, image and catalog formats and access modes.

301.03

Solar System Science with WISE

Robert S. McMillan¹, WISE Team ¹Univ. of Arizona.

10:24 AM - 10:36 AM

Ballroom 6B

WISE has surveyed the solar system to unprecedented sensitivity and resolution in its wavelength bands. Corresponding to the peak of thermal emission of many solar system bodies and particles, the 12 and 22 micron bands detected asteroids, comets, comet debris trails, and zodiacal dust to several AU from the sun. Some of the objects and material are too dark to have been detected by visible-light surveys, and

previous infrared telescopes in space have either not covered the whole sky or have had far less sensitivity. As a consequence, WISE explores the spatial distributions and thermal properties of the objects and material populating the inner solar system efficiently and without bias favoring bright albedos. At the temperatures dominant in the inner solar system, IR flux is more directly related to the size of the emitter than is visible flux, so the detections of asteroids by WISE are relatively insensitive to albedo. Yet combined with visual magnitudes, WISE data yield albedos. Orbital migration driven by asymmetrical thermal reradiation of absorbed sunlight depends on size and albedo, and affects the evolution of the orbits of asteroids. The distributions of sizes of asteroids, and the dependences of those distributions with orbital parameters to be uncovered by WISE are therefore evidence of the processes that brought the solar system to its current state. Dark asteroids that approach Earth are especially menacing if they have evaded detection by ground-based surveys, so WISE has refined knowledge of the impact hazard. WISE data help the study of the formation of cometary comae, tails, and dust trails, and the rate of mass loss from comets. Finally, the zodiacal dust bands, being the asteroidal component of the zodiacal dust, hold the key to determining the magnitude of the asteroid component.

301.04

Pursuing the Coldest Brown Dwarfs with WISE

J. Davy Kirkpatrick¹ ¹Caltech. 10:36 AM - 10:48 AM Ballroom 6B

The coolest brown dwarfs currently known are field T9 and T10 dwarfs with Teff~450-600K and implied masses of around 5-35 MJup for assumed ages of 1-10 Gyr. Colder field brown dwarfs must exist because studies of young star formation regions have revealed objects even lower in mass, which, at the age of the field population, will have cooled to temperatures well below 450K. Finding and characterizing such cold objects will set important boundary conditions on the shape of the initial mass function at the lowest masses, will help determine the low-mass cutoff for star formation, and will provide low-temperature fiducials important to the study of exoplanet atmospheres. Also of interest is determining the spectroscopic morphology of these colder objects; will a new spectral class beyond T, dubbed "Y", be needed? In this talk, I will highlight preliminary brown dwarf discoveries from the Wide-field Infrared Survey Explorer (WISE).

301.05 Highlights from WISE Galactic Science Deborah Padgett¹

¹Caltech. 10:48 AM - 11:00 AM Ballroom 6B

The Wide-field Infrared Explorer (WISE) all-sky survey will supply mid-infrared spectral energy distributions to most of the objects detected in the near-IR 2MASS survey. This makes the WISE database ideal for detecting and characterizing stars with `warm'

infrared excess out to 12 and 22 microns. Using these data, the WISE science team has found new candidate debris disks around nearby stars and white dwarfs. The team is also studying the population of star-forming clouds in regions outside of those mapped by targeted surveys. This talk will discuss highlights of WISE investigations of galactic infrared excess stars and diffuse nebulosity.

301.06

WISE Extragalactic Science

Peter R. Eisenhardt¹, D. Benford², A. Blain³, C. Bridge³, R. Cutri⁴, E. Donoso⁴, R. Griffith⁴, T. Jarrett⁴, S. Lake⁵, C. Lonsdale⁶, F. Masci⁴, S. Petty⁵, S. A. Stanford⁷, C. Tsai⁴, E. L. Wright⁵, J. Wu¹, L. Yan⁴ ¹JPL, ²GSFC, ³Caltech, ⁴IPAC, ⁵UCLA, ⁶NRAO, ⁷UC Davis. 11:00 AM - 11:12 AM Ballroom 6B NASA's Wide-field Infrared Survey Explorer (WISE) completed its first complete survey of the sky on

2010 July 17. A key scientific objective of the survey is to identify the most luminous, dusty, star forming galaxies in the Universe. I will summarize some of the initial extragalactic results from WISE, ranging from local compact star-forming galaxies to hyper-luminous IR galaxies at z > 2.

301.07

Cool Astronomy: Education and Public Outreach for the WISE mission Bryan J. Mendez $^{1}\,$

¹UC, Berkeley. 11:12 AM - 11:24 AM Ballroom 6B

The Education and Public Outreach (E/PO) program of the Wide-field Infrared Survey Explorer (WISE) aims to educate and engage students, teachers, and the general public in the endeavor of science. We bring a collection of accomplished professionals in formal and informal astronomy education from around the nation to create learning materials and experiences that appeal to broad audiences. Our E/PO program trains teachers in science, technology, engineering, and mathematics (STEM) topics related to WISE; creates standards-based classroom resources and lessons using WISE data and WISE-related STEM topics; develops interactive programming for museums and science centers; and inspires the public with WISE science and images.

302

Exoplanet Detection: Imaging, Interferometry Oral Session *Ballroom 6C*

302.01

Direct Imaging Discovery of a Fourth Planet at 15AU in the HR 8799 Planetary System Christian Marois¹, B. Macintosh², Q. Konopacky², T. Barman³, B. Zuckerman⁴ ¹*NRC Herzberg Institute of Astrophysics, Canada,* ²*Lawrence Livermore National Laboratory,* ³*Lowell Observatory,* ⁴*UCLA.* 10:00 AM - 10:10 AM

Ballroom 6C

We present the imaging discovery of a fourth planet at 0.376 arcsec (14.8 AU) projected separation from the young nearby star HR8799. This new object, designated HR8799e, is detected at Ks- and L-band wavelengths using the ADI observing technique with adaptive optics and the Keck II telescope on Mauna Kea. Over a 1-year baseline the object is confirmed as co-moving with the primary, revolving counter-clockwise like the three other known planets of this system, and it has similar brightness at Ks and L to HR8799c and d and hence likely similar mass, 10 times the mass of Jupiter. HR8799 has now been shown to possess the same number of gas giant planets as our Solar System, further adding to the various similarities between the two systems.
302.02

Recovery of Fomalhaut b with HST/STIS

Paul Kalas¹, J. R. Graham², M. P. Fitzgerald³, M. Clampin⁴ ¹*UC, Berkeley,* ²*University of Toronto, Canada,* ³*UCLA,* ⁴*NASA GSFC.* 10:10 AM - 10:20 AM

Ballroom 6C

Fomalhaut (HD 216956) is a young (100 Myr) A4V star 7.7 pc from the Sun that harbors a dusty debris belt. An exoplanet candidate, Fomalhaut b, was discovered in optical data obtained with the Hubble Space Telescope in 2004 and 2006 using the Advanced Camera for Surveys. Here we show new broadband optical coronagraphic imaging of the Fomalhaut system using the Space Telescope Imaging Spectrograph. We recover Fomalhaut b approximately 0.5 arcsec north of its 2006 position. The new data are consistent with a bound Keplerian orbit nested within the belt.

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Support was provided by NASA grant HST-GO-11818 from STScI, which is operated by AURA under NASA contract NAS5-26555. We also acknowledge University of California Lab Research Program 09-LR-01-118057-GRAJ and NSF grant AST-0909188.

302.03

A Young Exoplanet Caught at Formation

Adam L. Kraus¹, M. J. Ireland²

¹Univ. of Hawaii-IfA, ²University of Sydney, Australia. 10:20 AM - 10:30 AM

Ballroom 6C

Young and directly-imaged exoplanets offer critical tests of planet-formation models that can't be matched by RV surveys of mature stars. These targets have been extremely elusive to date, with no exoplanets younger than ~10-20 Myr and only a handful of direct-imaged exoplanets at all ages. We will report the first direct detection of a young exoplanet during its epoch of formation (T~2 Myr); this discovery was achieved using adaptive optics imaging combined with aperture mask interferometry, a technique that achieves extremely deep sensitivity at the diffraction limit of the telescope. The new planet is embedded in a protoplanetary disk with a large cleared gap (a ``transitional disk'') and orbits within that gap. Based on the substantial mass of the circumstellar disk and the very red colors of the planet, we propose that the planet is still accreting mass out of the circumstellar disk through a circumplanetary disk or shell. We will discuss this discovery in the context of our ongoing survey to identify planets in transition disk gaps, including its implications for the process, epoch, and duration of planet formation.

302.04

Non-redundant Aperture Masking Constraints on Massive Companions within 12 AU of the HR 8799 System

Sasha Hinkley¹, J. M. Carpenter¹, M. Ireland², A. L. Kraus³

¹California Institute of Technology, ²University of Sydney, Australia, ³University of Hawaii. 10:30 AM - 10:40 AM

Ballroom 6C

We report the results of L-band non-redundant aperture masking observations of the HR 8799 system obtained during two dedicated nights at Keck 2 using the NIRC2 camera operating with adaptive optics. With these measurements we are able to place upper limits on any massive additional companions to the system within ~300 miliarcseconds (~12 AU) of the star. We are able to reach contrasts of roughly 10^-2 at several tens of miliarcseconds (a few AUs) and at least 10^-3 at 50-300 miliarcseconds (~2 - 12

AUs). A key feature of aperture masking is its ability to reach contrasts approaching 10^-3 well within the Keck L-band diffraction limit (~70 mas), impossible with direct imaging. The small inner working angle afforded by aperture masking thus naturally complements direct imaging techniques such as Angular Differential Imaging which are very sensitive at inner working angles beyond ~500 miliarcseconds. At these contrasts we are able to probe planetary masses several times that of the three known companions themselves (7 to 10 Jupiter masses), and these observations will help complete our understanding of the true distribution of companions in this system. We will present robust detection limits derived using both our observing nights combined together, and derive upper limits to close-in companions from these limits. The presence or lack of additional companions at small inner working angles out of reach to the direct imaging techniques will have significant implications for the dynamical understanding of this intriguing system.

This work was performed [in part] under contract with the California Institute of Technology (Caltech) funded by NASA through the Sagan Fellowship Program.

302.05

Constraining the True Mass and 3d Orbit of Companions beyond the Ice Line

Justin R. Crepp¹, J. A. Johnson¹ ¹*California Institute of Technology.* 10:40 AM - 10:50 AM

Ballroom 6C

Precision radial velocity measurements have established long time baselines and are now starting to discover planets that reside beyond the ice-line in orbit around nearby stars. The number of companions appears to be growing as a function of semi-major axis and many stars exhibit trends that hint at the existence of additional companions with yet longer periods. We are conducting a sensitive high-contrast imaging program at Keck targeting stars that are being accelerated by a distant body. By combining two powerful and complementary planet detection techniques, we show that it is possible to place tight constraints on the true mass and 3d-orbit of such objects.

302.06

Commissioning Results From The VLTI PRIMA Facility Gerard van Belle¹

¹European Southern Observatory, Germany.

10:50 AM - 11:00 AM

Ballroom 6C

Commissioning work on the Phase Referenced Imaging and Microarcsecond Astrometry (PRIMA) Facility for ESO's Very Large Telescope Interferometer (VLTI) has been ongoing at Paranal Observatory. Intensive commissioning activity at the subsystem level has been taking place, testing the dual fringe sensor units, telescope star separators, internal system metrology, and differential delay lines. Results at the system level from the first commissioning runs will be presented, including dual simultaneous fringe tracking of PRIMA's twin fringe sensor units. Near-term prospects for PRIMA to achieve astrometric operations will also be presented, producing narrow-angle astrometry at the level of tens of microarseconds.

302.07

A New 24 micron Phase Curve for upsilon Andromedae b

Ian J. M. Crossfield¹, B. M. S. Hansen², J. Harrington³, J. Y. K. Cho⁴, D. Deming⁵, K. Menou⁶, S. Seager⁷ ¹UC Los Angeles, ²UC Los Angeles & UCLA Institute of Geophysics & Planetary Physics, ³University of Central Florida, ⁴Queen Mary, University of London, United Kingdom, ⁵NASA/Goddard Space Flight Center, ⁶Columbia University, ⁷Massachusetts Institute of Technology. 11:00 AM - 11:10 AM

Ballroom 6C

We report the detection of 24 um variations from the planet-hosting upsilon Andromedae system consistent with the orbital periodicity of the system's innermost planet, upsilon And b. Fitting a simple model with two hemispheres of constant surface brightness to our observations gives a peak-to-valley phase curve amplitude of 0.00130 times the mean system flux. Assuming a planetary radius of 1.3 RJup, this corresponds to a planetary temperature contrast of >900 K and an orbital inclination of >25 deg. We further report the largest phase offset yet observed for an extrasolar planet: the flux maximum occurs 80 deg before phase 0.5. Such a large phase offset is difficult to reconcile with most current atmospheric circulation models. We improve on earlier observations of this system in several important ways: (1) observations of a flux calibrator star demonstrate the MIPS detector is stable to 10⁴ on long timescales, (2) we note that the background light varies systematically due to spacecraft operations, precluding use of this background as a flux calibrator (stellar flux measured above the background is not similarly affected), and (3) we calibrate for flux variability correlated with motion of the star on the MIPS detector. A reanalysis of our earlier observations of this system is consistent with our new result.

303

Supermassive Black Holes Oral Session Ballroom 6A

303.01D General Relativistic MHD Models of Sgr A* and M87 Jason Dexter¹

¹University of Washington. 10:00 AM - 10:20 AM

Ballroom 6A

Ongoing high resolution observations of the Galactic center black hole provide a direct probe of the structure of its accretion flow (Sgr A*) on event-horizon scales. Due to its low luminosity, this source is uniquely suitable for modeling with relativistic MHD simulations. We perform time-dependent, relativistic radiative transfer on 3D simulation data to compute images and light curves of Sgr A* at millimeter wavelengths. Fitting the images to observations allows us to constrain the parameters of the accretion flow and black hole. Simulations with misaligned angular momentum and black hole spin axes ("tilted") are also considered. Due to the precession of these accretion flows, the inferred best fit parameters should appear to change on week timescales if Sgr A* is tilted. Light curves from all simulations exhibit flaring behavior consistent with the observations. The black hole shadow, a signature of the event horizon, is visible in all best fit models and may be detected in the next 5-10 years. Preliminary results from similar models of M87 are also discussed.

303.02D

Dynamical and Radiative Modeling of Sgr A* Roman Shcherbakov¹

¹Harvard University.

10:20 AM - 10:40 AM

Ballroom 6A

I will review a series of projects aimed at understanding the accretion onto the Galactic Center BH completed over the course of my PhD. First, the question of very low accretion rate onto Sgr A* was resolved. The initial guess that the accretion is inhibited by magnetic fields was dismissed, since the magnetized flow was found to achieve ~10-100% of spherical Bondi accretion rate. Subsequently, conduction appeared to effectively transfer energy from near the BH to outer radii stopping the inflow

down to 1% of Bondi rate. The conduction model with realistic feeding from stellar winds reconciled the theory and X-ray observations of surface brightness profile within 5" from Sgr A*. The discovered state of the outer flow served as a boundary condition for the inner flow modeling. The unrivaled combination of cutting-edge 3D GRMHD simulations and the original GR polarized radiative transfer code was employed to reach close to the BH horizon. The best fit to sub-millimeter spectrum and known linear and circular polarization fractions has BH spin 0.9, inclination 59deg, accretion rate 1.3*10⁻⁸ Msun/yr. To accurately compute the circular polarization the corrected expressions were derived for Faraday conversion measure. Contrary to the previous theory it happened to diminish for both small and large particle energies, peaking at intermediate energies En~several*m_e for observed frequencies. The performed research has far-reaching implications on dynamical and radiative modeling of other LLAGNs and jets. The work is partially supported by NESSF.

303.03D

Flares from the Tidal Disruption of Stars by Massive Black Holes in Galactic Nuclei Linda Strubbe¹, E. Quataert¹

¹UC Berkeley. 10:40 AM - 11:00 AM Ballroom 6A

A star that wanders too close to a massive black hole (BH) gets shredded by the BH's tidal gravity. Stellar gas soon falls back to the BH at a rate initially exceeding the Eddington rate, releasing a flare of energy as gas accretes. How often this process occurs is uncertain at present, as is the physics of super-Eddington accretion (which is relevant for BH growth and feedback at high redshift as well). Excitingly, transient surveys like the Palomar Transient Factory (PTF), Pan-STARRS and LSST should shed light on these questions soon -- in anticipation, we predict observational properties of tidal flares. Early on, much of the falling-back gas should blow away in a wind, producing luminous optical emission that are likely imprinted with blueshifted UV absorption lines. If the gas shocking close to the BH is unable to reach thermal equilibrium, the emission will instead be hard X-rays with no optical/UV lines. At later times, the gas accretes in a disk; for $M_{BH} \simeq 10^5 - 10^6$ Msun, 1-10% of the disk's emission is reprocessed by escaping stellar debris, producing a spectrum of very broad emission lines. We predict detection rates for PTF, Pan-STARRS and LSST, and discuss the substantial challenge of disentangling these events from supernovae. These surveys should significantly improve our knowledge of stellar dynamics in galactic nuclei, the physics of super-Eddington accretion, the demography of IMBHs, and the role of tidal disruption in the growth of massive BHs. We gratefully acknowledge support from the Miller Institute, UC Berkeley, NASA, and the Packard Foundation.

303.04

Towards the Detection of General Relativity and Dark Matter with Stellar Orbits at the Galactic Center: Improving Reference Frame Stability

Sylvana Yelda¹, A. M. Ghez¹, J. R. Lu², W. Clarkson³, J. Anderson⁴, T. Do⁵, K. Matthews²

¹UCLA, ²Caltech, ³Indiana University, ⁴Space Telescope Science Institute, ⁵UC Irvine.

11:00 AM - 11:10 AM

Ballroom 6A

Given current astrometric precision, observations from the Keck II 10 m telescope have the potential to reveal the effects of general relativity and extended mass on the orbits of stars around the Milky Way's central supermassive black hole, Sgr A*. However, one of the dominant uncertainties in these measurements will be reference frame stability, as an unstable reference frame may produce what appears to be a precession in a star's orbit. In this presentation, we discuss the refinements we have made in constructing the Galactic center astrometric reference frame and show that Sgr A* is localized

to within a position of 0.6 mas and a velocity of 0.09 mas/yr, or ~3.4 km/s at 8 kpc (1 sigma), a factor of 3 improvement over previous efforts. The two refinements come from improving our knowledge of the optical distortion solution of the NIRC2 camera and from defining a reference frame based on VLA measurements of SiO masers in the Galactic center. While earlier proper motion studies defined a reference frame by assuming no net motion of the stellar cluster, this approach is fundamentally limited by the cluster's intrinsic dispersion and therefore will not improve with time. The stability of our new reference frame should improve steadily with future measurements of the SiO masers in this region (proportional to $t^{(3/2)}$). This is essential for achieving the necessary reference frame stability required to detect the effects of GR and extended mass on short-period stars at the Galactic center.

304

Early Science with the Expanded Very Large Array Special Session *Room 611/612*

304.02

EVLA Observations of the Largest TNOs

Bryan J. Butler¹, M. A. Gurwell², A. Moullet² ¹NRAO, ²Harvard-Smithsonian CfA. 10:05 AM - 10:16 AM Room 611/612

Despite the importance of understanding TNOs in the context of solar system formation and evolution, the physical properties of these bodies are relatively poorly known. Though masses are known for at least those with satellites, their radii are poorly constrained, making estimates of such a fundamental quantity as density highly uncertain. Little is also known about the surface temperatures of these bodies; equilibrium with solar radiation is usually assumed.

Long wavelength thermal emission observations are a powerful way to constrain such quantities more accurately. They additionally sample below the surface (to roughly 10 wavelengths), yielding information about thermal and structure characteristics to that depth. Unfortunately, long wavelength emission is weak and has only been done successfully at millimeter wavelengths for a few of the largest TNOs. The EVLA is the next generation centimeter wavelength telescope, building on the tremendous success of the VLA. The main improvement is an eventual factor of 10 better sensitivity. Observations at a wavelength of 1 cm of the TNOs 2002 TC302, Makemake, Quaoar, and Eris, along with the Pluto system and Triton have been approved for the EVLA, and we will present all data taken on these bodies. This is part of a longer term program to measure the microwave emission spectrum of these bodies from roughly 0.5 mm to 5 cm using both the EVLA and ALMA.

304.04

Grain Growth and Sub-Structure in Protoplanetary Disks

David J. Wilner¹, C. Chandler², S. Andrews¹, N. Calvet³, J. Carpenter⁴, S. Corder², A. Deller², C. Dullemond⁵, J. Greaves⁶, T. Henning⁵, A. Isella⁴, J. Lazio⁷, H. Linz⁵, L. Mundy⁸, L. Perez⁴, L. Ricci⁹, A. Sargent⁴, S. Storm⁸, L. Testi⁹

¹Harvard-Smithsonian, CfA, ²NRAO, ³University of Michigan, ⁴Caltech, ⁵MPIfA, Germany, ⁶St. Andrews, United Kingdom, ⁷JPL, ⁸University of Maryland, ⁹ESO, Germany. 10:17 AM - 10:28 AM

Room 611/612

I will describe the Disks@EVLA program to survey protoplanetary disks around pre-main-sequence stars in the nearest star forming regions (Taurus, Ophiuchus, TW Hya) to investigate the millimeter/centimeter emission from large dust particles, the last observable link in the chain from sub-micron interstellar grains to planets. At these long wavelengths, dust emission is optically thin and probes the entire disk volume, including the innermost regions that become opaque in the submillimeter. Taking advantage of the new capabilities of the EVLA, we are using a staged approach that starts with photometry of approximately 60 disk systems, currently underway, to be followed by higher resolution imaging of smaller subsets of the brighter sources, ultimately reaching scales comparable to the orbital radius of Jupiter. Key goals include (1) determining the prevalence and location of grain growth to centimeter-sized "pebbles" from spectral indices, and any dependencies on stellar properties and environment, and (2) detecting physical sub-structures such as holes and gaps indicative of disk evolution and planet formation.

304.01

An EVLA Diagnostic K-Band Survey of Massive Young (Proto)stellar Objects Crystal L. Brogan¹, T. Hunter¹, C. Cyganowski², R. Indebetouw³, C. Chandler¹, R. Friesen¹ ¹NRAO, ²CfA/Harvard, ³NRAO/University of Virginia. 10:29 AM - 10:40 AM Room 611/612

We will present early results from a comprehensive study of 25 massive young stellar objects (MYSOs) at ~24 GHz (13mm) utilizing the power of the new EVLA WIDAR correlator to simultaneously observe the ammonia ladder through (6,6), the 25GHz methanol ladder, SO2, HC5N, recombination lines, and continuum at an angular resolution of ~10,000 AU. The selection criteria included: previous ammonia detections at (1,1) and (2,2), (sub)mm dust cores, a range of maser activity, and a range of 24micron luminosities and 8/24 micron colors. Together, the observed tracers provide the gas temperature, the frequency and strength of hot core emission, and the kinematics of cores, outflows, and ionized gas, all observed with a uniform sensitivity and resolution. With this wealth of data we aim to identify the best discriminators of MYSO evolutionary state, and ultimately better understand the process of massive star formation.

304.07

Radio Continuum Emission from Classical Novae: eNova Project Early Results (and Surprises!) Miriam Krauss¹, J. Sokoloski², L. Chomiuk¹, M. Rupen¹, N. Roy¹, G. Hallinan³, A. Mioduszewski¹, M. Bode⁴, S. Eyres⁵, G. Knapp⁶, T. O'Brien⁷

¹NRAO, ²Columbia University, ³National University of Ireland, Ireland, ⁴Liverpool John Moores University,

United Kingdom, ⁵University of Central Lancanshire, United Kingdom, ⁶Princeton University, ⁷University of Manchester, United Kingdom.

10:41 AM - 10:52 AM

Room 611/612

We present initial results from the eNova Project, an EVLA campaign to observe nearby classical novae at early times with high-bandwidth, multi-frequency coverage. Because radio emission is not subject to extinction by dust, and because it remains optically thick at lower densities than optical emission, it is an ideal probe of the physical parameters of nova explosions. Simple models for radio light curves have historically been based on a picture in which thermal, ionized gas produces homogeneous, expanding ejecta. These models provided reasonable descriptions of previous radio data. However, this simplistic picture is incompatible with our EVLA observations of two novae --- V407 Cyg and V1723 Aql. We will discuss the discrepancies between the simple models and our new EVLA data, which promise to provide new information about the explosion, the ejecta, and the circum-binary environment.

304.05

EVLA Constraints on the Progenitors of Supernovae Type Ia

Laura Chomiuk¹, A. M. Soderberg², R. Chevalier³, C. Badenes⁴, C. Fransson⁵ ¹Harvard-Smithsonian Center for Astrophysics, ²Harvard University, ³University of Virginia, ⁴Tel Aviv University, Israel, ⁵Stockholm University, Sweden.

10:53 AM - 11:04 AM

Room 611/612

While Type Ia supernovae are used increasingly as cosmological probes to trace the expansion history of the Universe, the nature of their progenitors remains enshrouded in mystery. In the favored model for these explosions, a white dwarf accretes material from a hydrogen-rich donor star (e.g. red giant). A necessary implication of this model is the production of weak radio emission as the SN blastwave plows through the wind of the donor star. Previous radio searches for this signal have been unsuccessful, largely attributed to the fact that the expected emission lay just beyond the VLA sensitivity. Here we present recent results from our EVLA program, which utilizes the increased sensitivity to search for the expected signal from SNe Ia. The non-detection of radio emission with the EVLA would indicate double-degenerate progenitor systems (binary white dwarf) or require serious modifications to the single-degenerate model.

304.06

The Bimodal Luminosity Distribution of QSOs: Starbursts and AGN? Kenneth I. Kellermann¹, A. E. Kimball¹, J. J. Condon¹, R. Perley¹, Z. Ivezic² ¹NRAO, ²University of Washington. 11:05 AM - 11:16 AM *Room 611/612* In spite of nearly 50 years of study, it is still unclear whether or not the radio emission from QSOs is bimodal consisting of distinct radio loud and radio quiet populations. New 5 GHz EVLA observations exploit two recent developments: a) the availability of the recent DR7 SDSS to provide a volume limited sample of 197 confirmed QSOs (M< -23) within the narrow range 0.2 < z < 0.3; and b) the dramatic improvement in radio continuum sensitivity made possible by the increased bandwidth of the EVLA which lets us detect, with only 10 minutes of integration, a source as faint as L = 10^22 W/Hz, well below the value which separates star-forming galaxies from AGN. We report on early results from the EVLA on a sub set of our QSO sample. Previous studies have been limited by the inhomogeneity of the optical QSO sample, inadequate sensitivity to fully sample the radio quiet population, the degeneracy between redshift and luminosity for flux density limited samples, as well as by strong evolution over the wide range of observed redshifts.

304.03

Imaging Molecular Gas in Primeval Galaxies with the EVLA

Chris Luke Carilli¹, D. Riechers², F. Walter³, J. Wagg⁴, E. Daddi⁵, R. Wang¹ ¹NRAO, ²Caltech, ³MPIA, Germany, ⁴ESO, Chile, ⁵Saclay, France. 11:17 AM - 11:30 AM

Room 611/612

The EVLA has opened a new window on the high redshift Universe through spatially and spectrally resolved imaging of the low order transitions from common molecules. These studies reveal the cool gas that fuels star formation in nascent galaxies. We will present the first results of CO imaging of distant galaxies with the EVLA during early science. These include: (i) two of the most distant extreme starburst (ie. submm) galaxies at z = 4.0 and 5.3, (ii) three near-IR selected star forming galaxies (sBzK) at $z \sim 2$, (iii) two strongly lensed Ly-break galaxies at $z \sim 3$, and (iv) three $z \sim 6$ quasar host galaxies. We derive total gas masses from the low order transitions, implying gas to stellar mass ratios of order unity in these early systems. A comparison with the higher order transitions shows evidence for extended, lower excitation molecular gas components in all cases besides the quasar hosts.

305

Ultraviolet Astronomy in the New Detector Era Special Session *Room 615/617*

305.01

High Performance UV Detectors: Enabling the Next Generation of Transformational UV Missions Christopher D. Martin¹

¹Caltech. 10:00 AM - 10:15 AM Room 615/617

In order for the next UV missions to be both transformational and affordable, UV detector technology must achieve the high efficiency and low noise that is routine for the visible band. We describe our on-going Caltech/JPL effort and early successes at reaching this goal. We show that these detectors will

make possible highly multiplexed, efficient, and scientifically compelling new investigations that directly address core scientific questions raised by the Astro2010 Decadal Survey. Finally, we discuss a possible strategy for the 2010's that will position a UV mission to be highly ranked in the next decadal survey.

305.02

UV Imaging Detectors: High-QE EBCMOS Enabling New Science Missions

Charles L. Joseph¹, B. E. Woodgate²

¹*Rutgers Univ.,* ²*Goddard Space Flight Center.*

10:15 AM - 10:30 AM

Room 615/617

The EBCMOS (electron-bombarded CMOS) is an excellent general-purpose ultraviolet detector with photon-noise-limited performance. Visible-blind ultraviolet sensors with detective quantum efficiencies of 30% to 70% have been demonstrated, representing a 2x - 3x improvement in sensitivity over traditional photocathode detectors. The Electron-bombarded CCD and now EBCMOS with an opaque photocathode on a smooth surface offers the best photocathode QE. Ongoing research, including nanowire technology, is likely to provide an assortment of new photocathodes, each with an optimal QE and customized wavelength range. The red cutoff is particularly important for a UV detector since most astronomical targets emit 10⁶ - 10⁸ visible photons for every UV photon, potentially swamping the UV signal. Novel magnet designs for the EBCMOS have enabled weight and volume reductions by a factor of 3, making it competitive in these parameters as well.

New science missions are enabled by EBCMOS detectors. One proposed mission is a near-UV longduration balloon mission having an integral field spectrograph (IFS) plus a Fabry-Perot with 0.1" resolution over a 100" x 100" field of view. Its 1.5 m aperture telescope plus its high sensitivity EBCMOS detector enable a factor of 25 advantage over GALEX in the NUV band. Moreover, the detector plays an important role in obtaining near diffraction limited resolution. The balloon mission will map Ly- α and O VI features in LAEs and LABs redshifted into the NUV (0.6 < z < 1.8). It will also map the outflows of multiply ionized gas from Seyfert AGNs. Another proposed mission which may incorporate EBCMOS detectors is an orbital observatory to map the circumgalactic medium (CGM) in the far UV using O VI, Ly- α , and C IV absorption/emission lines. This mission includes highly optimized spectral imagers with photon-counting detectors to make challenging observations without a high-performance attitude control system.

305.03

MCP Based UV Detectors, Their Evolution Through Many Astrophysics Missions and Their Future Scientific Applications

Oswald H. W. Siegmund¹

¹UC, Berkeley. 10:30 AM - 10:45 AM Room 615/617

Microchannel plate (MCP) electron imaging amplifiers were introduced in the early 1960s as an outgrowth of work on single channel continuous dynode multipliers, and have since become a mainstay of many classes of imaging system. Initially used as an element in image intensifiers, the MCPs direct sensitivity to electrons, ions, and x-rays have resulted in an enormous range of applications, from UV astronomy to electron spectroscopy. Over the past 28 years the Experimental Astrophysics Group (EAG) at the Space Sciences Laboratory have pioneered the development and use of photon counting detection devices based on MCP technology. Their use on a variety of successful space missions (e.g., SOHO, ALEXIS, ACE, ROSAT, HST-STIS, HST-COS, EUVE, CHANDRA, SAMPEX, IMAGE, FUSE, TIMED, ROSETTA, NEW HORIZONS, CHIPS and GALEX) operating from the visible to X-ray regimes for both

imagery and spectroscopy has demonstrated their high reliability, low power, low weight, operation at ambient temperature, immunity to the radiation environment of space, solar blindness and high temporal and spatial resolution. Improvements in quantum efficiency, spatial resolution and large format size are ongoing and are constructive in support on a number of upcoming Explorer proposal efforts and current studies for future missions. Though our research is currently aimed at developing a new type of MCPs for space astronomy missions, this technology will also be highly useful for imaging devices for biological, particle, atmospheric and homeland security/reconnaissance systems where MCPs are currently being utilized.

306

The Solar System Oral Session *Room 618/620*

306.01

Orbits and Masses of Near-Earth Triples 2001 SN263 and 1994 CC Julia Fang¹, J. Margot¹ ¹University of California, Los Angeles. 10:00 AM - 10:10 AM

Room 618/620

The existence and prevalence (~16%) of binary asteroids in the near-Earth population (Margot et al. 2002; Pravec et al. 2006) naturally lead to the search and study of multiple asteroidal systems. Triple systems are known to exist in the near-Earth population, the main belt, and the outer solar system. Among the near-Earth objects, there are currently only two well-established triples, 2001 SN263 (Nolan et al. 2008) and 1994 CC (Brozovic et al. 2009). We are interested in studying these systems to understand their dynamical interactions and to measure their physical properties. The datasets are based on Arecibo and Goldstone radar observations that resolve all components with decameter resolution. Due to the oblateness of the primary body and mutually interacting orbits, it is necessary to employ an N-body approach. After solving for the orbits and masses, we have run extensive stability tests that rule out some of the least-squares solutions. The components of 2001 SN263 have orbital periods of ~0.68 and ~6.3 days at semi-major axes of ~3.8 and ~16.8 km, respectively, with low eccentricities. The total system mass is of order 10¹³ kg and is known to 1% fractional precision. 1994 CC is characterized by orbital periods of ~1.2 and ~8.3 days, semi-major axes of ~1.7 and ~6.1 km, and eccentricities of ~0 and ~0.2. The total system mass is ~3 x 10^{11} kg and is known to 3% fractional precision. For both systems, we find mutual inclinations of order 10 degrees between the orbital planes of the satellites. The expectation of accurate shape models of the primary components (Brozovic et al., in prep.; Nolan et al., in prep.) combined with high-precision astrometry will allow us to perform an indepth dynamical analysis of these systems. Such an understanding may be applicable to other multicomponent or multi-planet systems.

306.02D

Characterization of Ultra-Wide Trans-Neptunian Binaries

Alex Parker¹, J. Kavelaars²

¹University of Victoria, Canada, ²NRC Herzberg Institute of Astrophysics, Canada.

10:10 AM - 10:30 AM

Room 618/620

As with binaries in other astrophysical settings, Trans-Neptunian binaries (TNBs) provide insight into the physical structure of their component bodies and the dynamical environment they are embedded in. A subset of the near-equal mass TNBs have very wide orbits, which are difficult to create and very

sensitive to perturbation. We performed an astrometric monitoring campaign for the largest existing sample of wide-separation, long-period TNBs for an extended period, and archival data has allowed us to sample baselines of up to a decade for some objects. We present the first-ever mutual orbit fits for each system, more than tripling the sample of ultra-wide TNBs with characterized orbits. We find that these systems are extremely sensitive to collisional disruption, and provide a handle on the small object (R~1km) population in the Kuiper Belt, for which there currently exists little observational constraint. In addition, due to the ease by which tidal impulses can disrupt these binaries, we find that a binary-bearing component of the Cold Classical Kuiper Belt was never subjected to a period of Neptune close encounters, and may have been formed in-situ.

306.03

On-Sky Detection Biases for Plutinos in the Kozai Resonance

Samantha Lawler¹, B. Gladman¹

¹University of British Columbia, Canada. 10:30 AM - 10:40 AM

Room 618/620

Because of their nearby location within the transneptunian region (a ~ 39.4 AU), the plutinos (objects in the 3:2 mean-motion resonance with Neptune) are especially well-studied, with 89 high-quality orbits currently listed in the Minor Planet Center database. We perform detailed modeling of the on-sky detection biases for plutinos that are simultaneously in the Kozai secular resonance. Kozai plutinos show periodic oscillations in eccentricity and inclination, with the argument of perihelion oscillating around 90 or 270 degrees with a given Kozai libration amplitude. Because of this, perihelion always occurs out of the plane of the ecliptic, biasing magnitude-limited ecliptic surveys against finding these objects. Lykawka & Mukai (2007, Icarus 189) determine that 22% of known plutinos are in the Kozai resonance, while Gladman et al. (2010, AJ submitted) estimate an intrinsic Kozai fraction of only 10% by debiasing the Canada-France Ecliptic Plane Survey (CFEPS). Surveys will detect different ratios of Kozai/non-Kozai plutinos depending on the ecliptic latitude and longitude, so debiasing to find the true ratio is complex. Even a survey that covers most or all of the sky will detect an apparent Kozai fraction that is different from the true fraction. The sky locations where non-Kozai plutinos peak in detectability depends on the libration amplitude, the inclination, and the eccentricity, as is true for all of the mean-motion resonances. Where the Kozai plutinos peak in detectability depends on the range of allowed Kozai libration amplitudes, which in turn affects the inclination and eccentricity. We present a "map" of the on-sky plutino Kozai fraction as will be detected by flux-limited surveys. This will be especially important for the Large Synoptic Survey Telescope (LSST) and Panoramic Survey Telescope & Rapid Response System (Pan-STARRS) projects which will both detect large numbers of plutinos as they sweep the sky.

306.04

The Cold Classical and Centaur Kuiper Belt Spectroscopic Families

Wesley Fraser¹, M. E. Brown¹

¹*California Institute of Technology.* 10:40 AM - 10:50 AM

Room 618/620

The surfaces of Kuiper belt objects exhibit an enigmatic physical diversity; with the exception of the largest methane-bearing objects, and those members of the Haumea family, the cause of the broad range of albedos and reflectance spectra exhibited by these objects remains all but unexplained. Trends in physical colour with other properties such as dynamical class suggest that different formation histories resulted in different spectral classes of object. The possibility of using the surface properties of Kuiper belt objects to constrain their genesis is a tantalizing prospect that requires a more indepth

understanding of the causes behind the diversity of these objects.

We have executed a large spectro-photometric survey of 120 Kuiper belt objects using WFC3 on HST. This large survey was designed to detect spectral features known to exist on bright objects, but on objects up to 3 magnitudes fainter than can be observed by ground-based observations. This uniform sample of high-quality observations has allowed us to identify two spectral classes of Kuiper belt object. The majority of objects in the cold-classical dynamical subclass, as well as the scattered disk and centaur subclasses have correlated optical and infrared colours that are common to that dynamical subclass alone. We find that a simple spectral absorbance model in which grain-size is the only variable can fully account for both the colours and albedos of the separate spectral classes. This simple yet successful model demonstrates that members of a spectral class exhibit virtually identical surface compositions which are different from the other classes. Other dynamical subclasses such as the resonant objects do not show a common spectral class, but rather are either mixtures of the two different spectral classes, or are objects which are undergoing surface evolution towards becoming members of one of these spectral classes.

306.05

A Search for Satellites of Kuiper Belt Object 55636 from the 2009 October 9 Occultation

Rebecca Jensen-Clem¹, J. L. Elliot¹, M. J. Person¹, C. A. Zuluaga¹, A. S. Bosh¹, E. R. Adams¹, T. C. Brothers¹, A. A. S. Gulbis², S. E. Levine³, M. Lockhart¹, A. M. Zangari¹, B. A. Babcock⁴, K. DuPre⁴, J. M. Pasachoff⁴, S. P. Souza⁴, W. Rosing⁵, N. Secrest⁶, L. Bright³, E. W. Dunham³, M. Kakkala⁷, T. Tilleman⁸, S. Rapoport⁹, L. Zambrano-Marin¹⁰, J. Wolf¹¹, K. Morzinski¹²

¹*MIT*, ²Southern African Large Telescope and South African Astronomical Observatory, South Africa, ³Lowell Observatory, ⁴Williams College, ⁵Las Cumbres Observatory Global Telescope Network, ⁶University of Hawaii, Hilo, ⁷University of Hawaii, Leeward Community College, ⁸United States Naval Observatory (USNO), ⁹Research School of Astronomy and Astrophysics, Mt. Stromlo Observatory, Australia, ¹⁰Nompuewenu Observatory, University of Texas Brownsville/Texas Southmost College, ¹¹SOFIA, Deutsches SOFIA Institute, NASA Ames Research Center, MS 211-3, ¹²Department of Astronomy and Astrophysics, University of California.

10:50 AM - 11:00 AM

Room 618/620

A world-wide observing campaign of 21 telescopes at 18 sites was organized by Elliot et al. (2010 Nature 465, 897) to observe the 2009 Oct. 9 stellar occultation of 2UCAC 41650964 (UCAC2 magnitude 13.1) by the Kuiper Belt object 55636 (visual magnitude 19.6). Integration times varied between 0.05 seconds at the Vatican Advanced Technology Telescope and 5 seconds at Mauna Kea mid-level. Data from the two sites that successfully observed the occultation (Haleakala and the Mauna Kea mid-level) were analyzed by Elliot et al. (2010) to determine the diameter and albedo of 55636. In this study, we use the entire data set to search for signatures of occultations by nearby satellites. One satellite previously discovered with occultation data is Neptune's moon Larissa, which was detected during Neptune's close approach to a star in 1982 (Reitsema et al. 1982). No satellites are found in this study, and upper limits will be reported on satellite radii within the volume probed (2 x 10⁻⁸ of the Hill Sphere). This work was supported, in part, by NASA Grants NNX10AB27G (MIT), NNX08AO50G (Williams College), and NNH08AI17I (USNO-FS) and NSF Grant AST-0406493 (MIT). Student participation was supported in part by NSF's REU program and NASA's Massachusetts Space Grant.

306.06

Using the EPOXI Mission to Measure the Dust Heterogeneity of Comet 103P/Hartley Michael S. Kelley¹, D. E. Harker², C. E. Woodward³, J. Licandro⁴, DIXI Team

¹Univ. of Maryland, ²UCSD/CASS, ³Univ. of Minnesota, ⁴Instituto de Astrofísica de Canarias, Spain. 11:00 AM - 11:10 AM

Room 618/620

The Deep Impact spacecraft will fly by comet 103P/Hartley on 4 Nov 2010 with a targeted closest approach distance of 700 km providing better than 50 m/pixel spatial resolution at the nucleus. In addition, comet 103P will fly by the Earth in October 2010 with a closest approach distance of 0.12 AU providing better than 100 km/arcsec resolution to Earth-based observers. Taking advantage of both flybys will help us connect nucleus geology observed by Deep Impact with coma morphology and composition, as measured by Deep Impact and Earth-bound telescopes. Because the Deep Impact spacecraft will only provide limited information on the composition of the dust coma, ground-based mid-infrared observations of comet 103P become especially important. Comet dust composition varies greatly from comet-to-comet. For example, comae range from the silicate rich comet C/1995 O1 (Hale-Bopp) (Harker et al. 2002, ApJ, 580) to the more moderate silicate composition of comet C/2002 V1 (NEAT) (Ootsubo et al. 2007, P&SS, 55) and the apparently silicate poor comet 2P/Encke (Kelley et al. 2006, ApJ, 651). But with our close encounters with comet 103P in 2010, we have an opportunity to instead examine the heterogeneity of a single comet nucleus. We present mid-infrared spectra of comet 103P along with near-infrared spectra from the Deep Impact spacecraft. We will discuss our effort to determine if the coma of this comet is homogeneous in terms of its dust grain properties (size, shape, and composition) and its implication on the dust of comets as a whole.

306.07

Earth-based Observing Campaign For Comet 103p/hartley 2 For The Dixi Mission

Karen Jean Meech¹, M. S. Kelley², M. F. A'Hearn², DIXI Observing Team

¹Inst. for Astronomy, ²University of Maryland.

11:10 AM - 11:20 AM

Room 618/620

The Deep Impact Extended mission (DIXI) is part of the EPOXI mission and will rendezvous with the comet 103P/Hartley 2 on 4 Nov. 2010 at 13:50 UT. Many of the anticipated key science results will come from the combined interpretation of the in-situ spacecraft data and the Earth- and space-based observing campaigns. DIXI in-situ objectives include characterizing the nucleus properties, understanding the activity (outbursts, and sources), mapping the surface and correlating surface albedo, color and temperature with topography to understand the thermal properties of the surface. The Earthbased observations provide a longer-term context for the in-situ observations, and will characterize the activity levels leading up to the encounter, including assessing the dust environment and volatile species production rates. Earth-based observations will search for outbursts and jets that might be linked to activity. The international observing campaign scheduled at more than 20 observatories, began in March 2010, and will continue beyond January 2011, although selected observations began in 2008 with the recovery of the nucleus (Snodgrass et al., (2010), A&A, 516L) and Spitzer IR observations (Lisse et al., (2009) PASP 121, 968), and in 2009 with the measurement of the rotational light curve. We will report on Earth-based observing highlights and their synergies with the in-situ observations. With these combined data we can not only better understand comet Hartley 2, but through the legacy of telescopic observations we may also better understand comets as a whole.

306.08 Comet Hartley 2 as Seen Up Close Michael F. A'Hearn¹, DIXI Team

¹Univ. of Maryland. 11:20 AM - 11:30 AM Room 618/620

The Deep Impact flyby spacecraft will have flown past comet 103P/Hartley 2 on 4 Nov 2010 to execute the Deep Impact eXtended Investigation (DIXI), the second half of the EPOXI mission. This will be the first opportunity to study two, quite different, cometary nuclei with the same instruments under similar conditions. Since Hartley 2 has a very small nucleus, very active for its size, the behavior must be very different from the behavior of Tempel 1, which has a large, relatively inactive nucleus. Some differences are already clear in the images from early approach, which show very large and slow variations in the production of CN relative to the dust, but the most dramatic differences will have been seen near closest approach. We might expect differences in the nuclear surface features, in the relative importance of jets (already seen in CN by ground-based observers), in the chemical heterogeneity of the outgassing, etc. We will present a summary of the key differences between a large nucleus with low activity and a small nucleus with high activity. Funded by NASA.

307

Stars, Cool Dwarfs, Brown Dwarfs Oral Session *Room 613/614*

307.01

A Near Infrared Study of Young Field Brown Dwarfs

Katelyn N. Allers¹, M. C. Liu², K. L. Cruz³ ¹Bucknell University, ²University of Hawai'i, ³Hunter College. 10:00 AM - 10:10 AM Room 613/614

We present the results of a near infrared spectroscopic survey of 53 M6-L8 type field dwarfs displaying evidence of youth (low-gravity). Our survey includes both low (R~150) and moderate (R~1200) resolution spectra. By examining FeH, VO, Na, K and H2O features, we have developed a set of criteria for estimating the relative ages of young brown dwarfs. We compare the signatures of low-gravity in the near-IR to those seen in the optical spectra of young field dwarfs. Using the relative ages determined for our sources, we examine the relationship between youth and near and mid-IR photometric colors. By using our age estimates and published proper motions, we assess membership of these young field objects in known young moving groups.

307.02D

Revealing Stellar Magnetic Fields Through M Dwarf Flares

Eric J. Hilton¹, S. L. Hawley¹, A. F. Kowalski¹ ¹Univ. Of Washington. 10:10 AM - 10:30 AM *Room 613/614* Magnetic reconnection on M dwarfs powers explose the blue/near-UV on timescales of minutes to bour

Magnetic reconnection on M dwarfs powers explosive flares with flux increases of several magnitudes in the blue/near-UV on timescales of minutes to hours. We obtained over 500 hours of flare monitoring observations at the Apache Point Observatory to make the first measurements of the flare frequency distribution of inactive early and mid M dwarfs and active late M dwarfs. These new measurements

combined with our studies of flare rates from both SDSS photometry and spectroscopy have allowed us to construct a model of M dwarf flaring in the Galaxy that predicts the number and magnitude of flares expected in a given survey. In addition to the implications for time-domain surveys such as LSST, Pan-STARRS, and PTF, and for planet-habitability, the rate of flaring on stars of different mass and age informs our knowledge of the formation and evolution of stellar magnetic fields. We find that the flare star distribution is more concentrated toward the Galactic mid-plane than the active star population, implying that they are younger. Active stars flare more frequently and with more energy than inactive stars. Flares on late-type active M dwarfs are less energetic than those on earlier types. We acknowledge support from NSF grant AST 08-07205.

307.03

Using the SLoWPoKES Catalog to Study the Spectroscopic Properties and Constrain Empirical Models of M Dwarfs

Saurav Dhital¹, A. A. West², K. G. Stassun¹, J. J. Bochanski³ ¹Vanderbilt University, ²Boston University, ³Pennsylvania State University.

10:30 AM - 10:40 AM

Room 613/614

The Sloan Wide Pairs of Kinematically Equivalent Stars (SLoWPoKES) catalog comprises of a sample of 1342 very wide, low-mass common proper motion pairs. The identification was based on angular separation, photometric distance, and component proper motions. A Galactic model, based on empirical stellar number density and space velocity distributions, was used to select pairs with a probability of chance alignment <5%. The selection criteria were purposely conservative to allow for efficient followup programs.

We report the results of a spectroscopic followup of 120 SLoWPoKES pairs using the KPNO 2.1-m telescope: (i) the matched radial velocity confirm the fidelity of the SLoWPoKES pairs, (ii) the metallicity sensitive zeta parameter proposed by Lepine et al. (2007), using CaH and TiO molecular band strengths, is robust in the Solar metallicity regime, and (iii) the H-alpha activity levels show that the West et al. (2008) activity-age relation can be used as a reliable age indicator for an ensemble but the magnitude of H-alpha fluctuations may limit its utility for individual stars. We are currently conducting follow-up work: (i) to calibrate the absolute metallicity scale using dG/dK-dM pairs, (ii) calibrating absolute ages using Wd-dM pairs, and (iii) testing the Barnes (2010) gyrochronology relations in low-mass stars. See http://www.vanderbilt.edu/astro/slowpokes/ for more details.

307.04D

Searching for Chemical Evidence of Planet Accretion in Red Giant Rapid Rotators

Joleen K. Carlberg¹, S. R. Majewski¹

¹University of Virginia.

10:40 AM - 11:00 AM

Room 613/614

Red giants stars are generally slow rotators, but a small fraction of them exhibit rapid rotation. The deposition of a planet's orbital angular momentum into the stellar envelope is one model that can account for this unusually rapid rotation. As the star evolves, it expands and fills the gap between itself and its planet. Eventually, the planet is near enough to cause stellar tides, and tidal torques can transfer the planet's orbital angular momentum to the stellar envelope.

If the planet is accreted, it can have a detectable effect on the chemical composition of the stellar envelope for elements that are either depleted during stellar evolution or that are preferentially enhanced in planets themselves. In the former case, the stellar convection envelope deepens into the hot stellar interior during first dredge-up, thereby depleting lithium by several orders of magnitude and decreasing the ratio of 12C to 13C by factors of 2 to 20. An accreted planet could replenish these depleted elements. An accreted planet could also preferentially enhance stellar abundances of refractory elements because planets are thought to form in environments where refractory elements are relatively enhanced compared to volatiles. At the very least, core accretion models predict the accumulation of rocky cores before the gaseous atmosphere of the planet forms. Armed with these expectations, I undertook a search for planet accretion signatures in a sample of rapid rotators. The rapid rotators and control stars were found in a sample of candidate giants for the Space Interferometry Mission's Astrometric Grid. Follow-up spectra at high S/N and high resolution were obtained for measuring precise abundances. In this talk, I will summarize the outcome of my search for chemical signatures of planet accretion. I will give conclusions drawn from the total sample and discuss a few individual cases.

307.05D

A Survey for Low-Mass Members of Nearby Young Moving Groups

Joshua E. Schlieder¹, S. Lepine², E. Rice², M. Simon¹

¹Stony Brook University, ²American Museum of Natural History.

11:00 AM - 11:20 AM

Room 613/614

Young stars free of the obscuring effects of their formation region exist in the Solar neighborhood as members of co-moving, ~coeval groups known as nearby young moving groups (NYMGs). Since identification of new members has relied on magnitude limited surveys, NYMGs are mostly F, G, and K type stars, with only the nearest M type members being represented. Thus, the census of known members is probably incomplete. NYMG members are important because they provide: 1) Well characterized samples of nearby young stars for study of their physical and kinematic properties, and 2) Prime targets for direct exoplanet imaging. We have therefore developed a general technique to identify low-mass candidates of NYMGs using proper motion and photometry. Candidates are then screened for secondary evidence of group membership, such as indicators of youth and consistent radial velocity, to identify likely new group members. Here we present results from our survey of Beta Pictoris (~10 Myr) and AB Doradus (~70 Myr) NYMG candidates. Our technique has identified more than 30 low-mass likely members of these groups with spectral types later than K3. Among the likely new members are many visual binaries and objects that are potentially benchmark young brown dwarfs. Our expanded member sample has also allowed us to begin studying the astrophysics of young late-type objects including binary properties and spectroscopic gravity indicators.

307.06

The Li And Be Dips Revisited: The Role Of Gyroscopic Pumping.

Pascale Garaud¹, P. Bodenheimer¹

¹UC Santa Cruz. 11:20 AM - 11:30 AM Room 613/614

The existence of a dip in the observed abundances of Li and Be in young stars in the mass range 1.3 to 1.5 solar masses strongly suggests the presence of an additional mixing mechanism to transport these elements from the outer convection zone down to the region where they are destroyed. However, no simple model to date has been able to reproduce simultaneously the respective amplitudes of the Li and the Be dips, as well as their shapes. We study here the effect of an important new mechanism for rotational mixing called "gyroscopic pumping", first noted for its importance in the dynamics of the solar interior, and find that it does indeed provide an elegant answer to this long-standing problem.

Gyroscopic pumping is a simple and very generic consequence of angular momentum conservation in differentially rotating convective regions. The perpetual azimuthal force driving the differential rotation also drives a large-scale meridional circulation through angular momentum conservation. We show here how, specifically for the mass range of the Li-dip stars, the flows thus pumped form a slow, large-scale "conveyor belt" between the inner convective core and the outer convection zone. Li- and Be-rich material flowing down from the outer regions is slowly replaced by Li- and Be-poor material flowing up from the inner regions. Meanwhile, turbulent mixing in the thin overshoot layer also replenishes the outer convection zone with Li- and Be-rich material.

Overall, the balance between advection by gyroscopic pumping and turbulent mixing by overshooting motions is found to provide a rather good agreement with observations of Li and Be, within a single and very simple framework.

This work was funded by an NSF CAREER award of the presenting author.

308 *Supernovae I - Type Ia* Oral Session *Room 609*

308.01

Analysis of the Type Ia Supernova SNF20080514-002

Rollin Thomas¹, G. Aldering¹, C. Aragon¹, P. Antilogus², C. Baltay³, S. Bongard², P. Brown⁴, C. Buton⁵, A. Canto², M. Childress¹, N. Chotard⁶, Y. Copin⁶, H. Fakhouri¹, E. Gangler⁶, M. Kerschhaggl⁵, M. Kowalski⁵, E. Hsiao¹, S. Loken¹, P. Milne⁷, P. Nugent¹, K. Paech⁵, R. Pain², E. Pecontal⁸, R. Pereira⁶, S. Perlmutter¹, D. Rabinowitz³, K. Runge¹, R. Scalzo³, G. Smadja⁶, C. Tao⁹, C. Wu²

¹LBNL, ²LPNHE, France, ³Yale, ⁴University of Utah, ⁵University of Bonn, Germany, ⁶IPNL, France, ⁷Steward Observatory, ⁸CRAL, France, ⁹CPPM, France.

10:00 AM - 10:10 AM

Room 609

We discuss the comprehensive analysis of spectrophotometric time-series observations of the Type Ia supernova SNF20080514-002. The data consist of 20 SuperNova Integral Field Spectrograph (SNIFS) spectra sampled over 50 days, commencing at 10 days before peak brightness. The analysis is part of a systematic effort to map out the time-dependent manifestation of ion species in Type Ia supernova spectra in detail. In general, the SN is relatively normal, but it possesses some noteworthy characteristics we explore in detail. C II footprints are detected in the spectra leading up to maximum light, suggesting that unburned material may be mixed with intermediate mass burning products. Though the light-curve qualifies as a moderately fast-decliner (s=0.87), its UV-optical colors are unusually blue. We attempt to place these findings into the context of supernova explosion models, and comment on whether the occurrence of carbon in lower-luminosity Type Ia supernovae favors any particular model or not.

308.02

Metallicity and the Nucleosynthesis of the Intermediate Mass Elements in Type Ia Supernovae David Chamulak¹, E. F. Brown², A. C. Calder³, A. P. Jackson³, B. K. Krueger³, F. X. Timmes⁴, D. M.

Townsley⁵

¹Argonne National Laboratory, ²Michigan State University, ³The State University of New York - Stony Brook, ⁴Arizona State University, ⁵The University of Alabama. 10:10 AM - 10:20 AM

Room 609

Type Ia supernovae (SNe Ia) are the premier standard candle for measuring the expansion history of the universe. SNe Ia make good standard candles only because their light curves can be calibrated. However, observations indicate even after calibration SNe Ia light curves have some dependence on properties of the host galaxy. Numerical models are steadily becoming more refined and can begin to probe the connection between the properties of the progenitor white dwarf and the outcome of the explosion. We perform numerical calculations to examine the effect of metallicity on the nucleosynthesis taking place in SNe Ia. Detailed yields resulting from explosive burning of the carbon/oxygen plasma in our models are examined using post-processing through a 532-nuclide reaction network. We explore how the production of elements from silicon to titanium varies with metallicity of the progenitor star. Our calculations suggest systematic trends in the silicon-group elements that may be observable. There is a clear trend with increasing metallicity of increasing silicon production while all other intermediate mass elements are produced in smaller abundances. We find, for example, that calcium follows a nearly linear trend of decreasing production with increasing metallicity.

This work was supported by the US Department of Energy, Office of Nuclear Physics, under contract DE-AC02-06CH11357.

308.03

The Transition to Turbulence of Rayleigh-Taylor Unstable Flames

Elizabeth P. Hicks¹, R. Rosner¹

¹University of Chicago. 10:20 AM - 10:30 AM Room 609

Part of the uncertainty surrounding the explosion mechanism of Type 1A supernovae is the extent to which the turbulence created by the flame front can speed the flame up. A premixed flame moving against a sufficiently strong gravitational field becomes deformed and creates vorticity. If gravity is strong enough, this vorticity is shed and deposited behind the flame front. We have completed some two-dimensional direct numerical simulations of this shedding process for various values of the gravitational force. If gravity is weak enough, the flame front remains flat and no vorticity is created. If gravity is slightly stronger, the flame front becomes cusped and creates vorticity; long vortices attach to the flame front and extend behind it. For even larger values of gravity, the far end of these vortices becomes unstable and sheds more vortices. For simulations with increased gravity, the position of the shedding instability moves closer to the flame front. Next, the vortex shedding disturbs the flame front, causing the flame to pulsate. These pulsations lose their left/right symmetry and the period of oscillation doubles. For even higher values of gravity, an additional frequency is introduced into the system as the Rayleigh-Taylor instability begins to dominate over burning. Eventually, the pulsations of the flame become guite complex and the interaction between the flame front and the vortices can't be simply described. We have measured the subsequent wrinkling of the flame front by computing its fractal dimension and the energy spectra behind the flame front. Measurements of the fractal dimension suggest that it saturates, implying that any additional speed up of the flame must be due to large-scale stretching or disruption of the flame front. Our simulations were performed at NERSC which is supported by the Department of Energy.

308.04

The Young Metal-Poor Host Galaxy of the Super-Chandrasekhar Type Ia SN 2007if

Michael Childress¹, G. Aldering², P. Antilogus³, C. Aragon², C. Baltay⁴, S. Bongard³, C. Buton⁵, A. Canto³, N. Chotard⁵, Y. Copin⁵, H. Fakhouri¹, E. Gangler⁵, E. Hsiao², M. Kerschhaggl⁶, M. Kowalski⁶, S. Loken², P. Nugent², K. Paech⁶, R. Pain³, E. Pecontal⁷, R. Pereira⁵, S. Perlmutter², D. Rabinowitz⁴, K. Runge², R.

Scalzo⁴, G. Smadja⁵, C. Tao⁸, R. C. Thomas², C. Wu³

¹University of California, Berkeley, ²Lawrence Berkeley National Lab, ³LPNHE, France, ⁴Yale University, ⁵IPNL, France, ⁶Universitat Bonn, Germany, ⁷CRAL, France, ⁸CPPM, France.

10:30 AM - 10:40 AM

Room 609

We present Keck LRIS spectroscopy and g-band photometry of the metal-poor, low-luminosity host galaxy of the super-Chandrasekhar mass Type Ia supernova SN 2007if. Deep imaging of the host reveals its absolute magnitude of $M_g \sim -14.5$. Optical color and spectral indices measured from the stellar continuum constrain the mass-to-light ratio, giving a host stellar mass estimate of $\log(M/M_{sun}) \sim 7.5$. These features also constrain the star-formation history of the galaxy, and show it to be dominated by a major starburst a few hundred Myr before the supernova itself. Using emission line fluxes from the spectrum, we determine the host metallicity to be very low (about 1/10th solar). Our data shows that SN 2007if, a key member of the emerging sub-class of probable super-Chandrasekhar mass SNe Ia, is very likely to have originated from a young metal-poor progenitor.

308.05D

Type Ia Supernova Rates from the HST Cluster Supernova Survey

Kyle H. Barbary¹, K. S. Dawson², G. Aldering³, R. Amanullah⁴, M. Brodwin⁵, N. Connolly⁶, M. Doi⁷, P. Eisenhardt⁸, L. Faccioli³, V. Fadeyev⁹, H. Fakhouri¹, A. S. Fruchter¹⁰, M. Gladders¹¹, G. Goldhaber¹, A. Goobar¹², T. Hattori¹³, E. Hsiao³, X. Huang¹, Y. Ihara⁷, N. Kashikawa¹⁴, K. Konishi⁷, B. Koester¹¹, M. Kowalski¹⁵, C. Lidman¹⁶, J. Meyers¹, L. Lubin¹⁷, T. Morokuma⁷, T. Oda¹⁸, N. Panagia¹⁰, S. Perlmutter¹, P. Ripoche³, M. Postman¹⁰, D. Rubin¹, P. Rosati¹⁹, D. J. Schlegel³, A. L. Spadafora³, M. Strovink¹, S. A. Stanford¹⁷, N. Suzuki³, N. Takanashi¹⁴, K. Tokita⁷, N. Yasuda⁷, Supernova Cosmology Project ¹University of California - Berkeley, ²University of Utah, ³Lawrence Berkeley National Lab, ⁴Oskar Klein Centre for Cosmo Particle Physics, Sweden, ⁵Harvard-Smithsonian Center for Astrophysics, ⁶Hamilton College, ⁷University of Tokyo, Japan, ⁸Jet Propulsion Laboratory, Caltech, ⁹University of California - Santa Cruz, ¹⁰Space Telescope Science Institute, ¹¹University of Chicago, ¹²Stockholm University, Sweden, ¹³National Astronomical Observatory of Japan, ¹⁶Australian Astronomical Observatory, Australia, ¹⁷University of California - Davis, ¹⁸Kyoto University, Japan, ¹⁹European Southern Observatory, Germany.

10:40 AM - 11:00 AM

Room 609

We present measurements of the Type Ia supernova rate in both high-redshift galaxy clusters and the field. For the first time, we detect a significant increase in the cluster rate with redshift, when compared to lower-redshift measurements. Our field rate measurement indicates an SN Ia rate that is flat or decreasing with redshift at z > 1, in general agreement with previous studies. These are results from the *Hubble Space Telescope* Cluster Supernova Survey (PI Perlmutter; see Dawson et al. 2009), in which we discovered a total of 20 SNe Ia, including the first nine SNe Ia ever discovered in z > 0.9 clusters, and eight z > 0.9 SNe Ia in the field. SN Ia rate meaurements provide one of the few available probes of the as-yet-unknown SN Ia progenitor system. The cluster rate provides a direct measure of the SN Ia delay time distribution, which can be used to differentiate between progenitor scenarios. Additionally, the cluster rate is a key factor for studies of the metallicity enrichment of the intracluster medium, and can even be used to constrain the population of intracluster stars. With our result, the cluster rate measurements alone constrain the SN Ia rate to decline with delay time as $t^{-1.3 \pm 0.9}$ and have already been combined with other measurements to yield tighter constraints (e.g., Maoz et al. 2010). Measurements of the high-redshift volumetric SN Ia rate test specific progenitor scenarios predicting a metallicity dependence of the SN Ia rate, and are an important input in designing future high-redshift SN

programs. This work has been supported by the Office of Science, U.S. Department of Energy, through contract DE-AC02-05CH11231 and in part by NASA through grants associated with HST-GO-10496.

308.06

Rates of Type Ia Supernovae in Low-Redshift Galaxy Clusters from the CFHT Multi-Epoch Nearby Cluster Survey

Melissa Graham¹, D. J. Sand¹, C. J. Pritchet², H. Hoekstra³, D. Zaritsky⁴, C. J. Bildfell²

¹LCOGT/UCSB, ²University of Victoria, Canada, ³Leiden University, Netherlands, ⁴University of Arizona. 11:00 AM - 11:10 AM

Room 609

The Multi-Epoch NEArby Cluster Survey (MENeaCS) is a completed search for Type Ia supernovae in 60 low redshift, x-ray luminous galaxy clusters. Executed over two years at a monthly cadence with MegaCam on the Canada-France-Hawaii Telescope, MENeaCS found 22 cluster SNe Ia, all of which were spectroscopically confirmed with follow-up observations. Four of these SNe Ia appear to be hostless, belonging to the intracluster stellar population. In this talk, we will demonstrate the constraints these hostless SNe Ia place on the fraction of light in the intracluster medium (ICM), and discuss the implications of these rates on the origins of the iron abundance in the ICM. We will also show the rate of SNe Ia in cluster galaxies, specifically in cluster ellipticals, and present the characteristics of SNe Ia hosts in our galaxy clusters.

308.07

Constraining Sn Ia Progenitor Scenarios with SNLS Time Series

Federica Bianco¹, D. A. Howell¹, D. Kasen², A. Conley³, M. Sullivan⁴, S. Gonzales-Gaitan⁵ ¹LCOGT-UCSB, ²UC Berkeley, ³university of colorado, ⁴Oxford University, United Kingdom, ⁵University of Toronto, Canada.

11:10 AM - 11:20 AM

Room 609

We used 3 years of SuperNova Legacy Survey (SNLS) data to constraint the SN Ia progenitor scenarios. We searched for an excess in the early portion of SNLS lightcurves, signature of shocking by a companion, as predicted in Kasen 2010. We find no evidence of such excess and we are able to constrain the contribution of single degenerate systems with a Red Giant donor to the type Ia SN progenitors to less then 10%.

309 Evolution of Galaxies VI Oral Session *Room 608*

309.01D

Cold Gas and Star Formation in Local Blue-Sequence E/S0s

Lisa H. Wei¹, S. N. Vogel², S. J. Kannappan³, A. J. Baker⁴, D. V. Stark³, S. Laine⁵ ¹Harvard-Smithsonian Center for Astrophysics, ²University of Maryland, ³University of North Carolina, ⁴Rutgers, The State University of New Jersey, ⁵Spitzer Science Center. 10:00 AM - 10:20 AM Room 608

Recent work has identified a population of local E/SO galaxies that lie on the blue sequence in color vs. stellar mass parameter space, where spiral galaxies typically reside. While some blue-sequence E/SOs must be young major merger remnants, many low-mass blue-sequence E/SOs appear much less disturbed, residing in low-density field environments where gas infall/accretion is possible. These

galaxies may provide an evolutionary link between traditional early-type galaxies and spirals through disk regrowth. We present a multi-wavelength study of low-mass blue-sequence E/S0s, focusing on the cold gas content and star formation in these galaxies. Based on GBT HI spectra, the atomic gas to stellar mass ratios for most blue-sequence E/S0s range from 0.1 to 1.0, comparable to those of spiral and irregular galaxies. We examine the relationship between molecular gas and star formation surface densities for selected E/S0s based on CARMA and IRAM 30m CO(1-0) observations and GALEX FUV/Spitzer MIPS 24 micron imaging. We find many of our blue-sequence E/S0s fall on the same Schmidt-Kennicutt relation as local spirals, although offset towards apparently higher molecular gas star formation efficiency. We present evidence that star formation in these galaxies is bursty and likely involves externally triggered gas inflows.

309.02D Building the Red Sequence Jared Gabor¹, R. Dave¹¹ ¹Univ. of Arizona.

10:20 AM - 10:40 AM Room 608

The formation of the red sequence remains a challenge for models of galaxy evolution. We test simplified models of star formation quenching, including quenching associated with mergers or a hot gas halo, in a cosmological context with fully hydrodynamic simulations. Due to difficulties with resolution and uncertainties in accretion physics, we avoid specifically invoking supermassive black holes in our models. Instead, we try to approximate the effects of feedback required to create the red sequence. Using straightforward prescriptions introduced on-the-fly in the simulations, I will show that alone, powerful galactic winds during major mergers cannot yield a substantial red sequence. In contrast, quenching models where we add energy to hot gas halos successfully match the z=0 red galaxy luminosity function. Since we track the full gas dynamics, this work opens windows to further constraints on feedback mechanisms, such as hot gas properties in galaxy groups and clusters.

309.03D

Low Surface Brightness Emission in the Outskirts of LBGs at z~3: Possible Star Formation in Atomicdominated DLA Gas

Marc Rafelski¹, A. Wolfe¹, H. Chen²

¹UCSD, ²University of Chicago.

10:40 AM - 11:00 AM

Room 608

We present evidence for spatially extended low surface brightness emission around Lyman break galaxies (LBGs), suggesting the presence of in situ star formation in gas associated with LBGs. We measure the emission in the V-band image of the Hubble Ultra Deep Field, corresponding to the z^3 rest-frame FUV light which is a sensitive measure of Star Formation Rates (SFRs). The outskirts of z^3 LBGs are too faint to accurately measure emission individually, therefore we create a stacked image of 48 z^3 LBGs that are compact, symmetrical, and isolated. We develop a theoretical framework to connect this emission around LBGs to the expected emission from surrounding neutral HI gas at high redshift, i.e., damped Lyman alpha systems (DLAs), using the Kennicutt Schmidt (KS) relation. Under the hypothesis that the observed FUV emission in the outskirts of LBGs is from in situ star formation in atomic dominated gas, we find that the SFR efficiency in neutral atomic-dominated hydrogen gas at z^3 is between factors of 10 and 50 lower than predictions based on the local KS relation. We also find that the metals produced by the in situ star formation in the outskirts of LBGs yield metallicities comparable to those of DLAs. This is a possible solution to the 'Missing Metals' problem, as long as the high

metallicity gas in the cores of LBGs does not significantly contaminate the DLAs. In addition, we find that the covering fraction of DLA gas is sufficient to explain the emission in the outskirts of LBGs, while the covering fraction of molecular gas is not adequate. Therefore, our results are consistent with the idea of gas in spatially extended DLAs encompassing compact LBGs that could be the fuel source for star formation in the LBGs.

309.04

On The Inconsistency Between The Estimates Of Cosmic Star Formation Rate And Stellar Mass Density In High Redshift Galaxies

Jun-Hwan Choi¹, K. Nagamine²

¹University of Kentucky, ²University of Nevada.

11:00 AM - 11:10 AM

Room 608

There are two different approaches to observe the cosmic star formation history: the direct star formation rate measurement and the stellar mass density.

Using cosmological smoothed particle hydrodynamics simulations based on the cold dark matter model, we study cosmic star formation history with two different approaches for high-z galaxies.

The comparison between the simulation results and the observed cosmic star formation rate shows good agreement, while the observed stellar mass density significantly lower than the simulation results. We discuss potential origins for this discrepancy such as the population of low mass galaxies, the initial mass function, the mass-to-light ratio, and the dust extinction correction.

309.05

On The Upper IMF in Nearby Dwarf Galaxies: Modeling the Effects of Star Formation Histories Daniel R. Weisz¹, B. D. Johnson², L. C. Johnson¹, E. D. Skillman³, LVL Team

¹Univ. of Washington, ²Cambridge University, United Kingdom, ³Univ. of Minnesota.

11:10 AM - 11:20 AM

Room 608

Observations of lower than expected H α -FUV flux ratios in nearby dwarf galaxies have led to suggestions that the upper stellar IMF may systematically vary with respect to environment. We investigate the influence of star formation histories (SFHs) on the H α -FUV flux ratios in nearby galaxies to assess the plausibility that SFHs could account for the observed trends. We model a wide range of SFH parameters, including some that resemble those of measured SFHs from studies of resolved stellar populations in nearby galaxies. Assuming a fully populated Chabrier IMF, we generate model predictions of the H α -FUV flux ratios, R-band surface brightness, and total stellar mass, and compare to observations of 127 nearby star forming galaxies from the LVL and SDSS samples. We find excellent agreement between the model SFH predications and the observed trends. We also explore the how extinction corrections, sample completeness, and choice of independent physical parameter (e.g., stellar mass, R-band surface brightness) can all introduce unphysical biases into the data. Our findings do not rule out competing effects such as photon leakage or stochastic sampling of the IMF, and are consistent with a combination of these effects causing the observed trends.

309.06

The Origin and Evolution of the Galaxy Star-Formation-Rate Sequence

Aaron A. Dutton¹, F. C. van den Bosch², A. Dekel³ ¹University of Victoria, Canada, ²Yale University, ³The Hebrew University, Israel. 11:20 AM - 11:30 AM

Room 608

We use a semi-analytic model for disk galaxies to explore the origin of the time evolution and small scatter of the galaxy SFR sequence --- the tight correlation between star-formation rate (SFR) and stellar mass (M_{*}). The steep decline of SFR from $z \sim 2$ to the present, at fixed M_{*}, is a consequence of the following: First, disk galaxies are in a steady state with the SFR following the net (i.e., inflow minus outflow) gas accretion rate. The evolution of the SFR sequence is determined by evolution in the cosmological specific accretion rates, \propto (1+z)^{2.25}, but is found to be independent of feedback. Although feedback determines the outflow rates, it shifts galaxies along the SFR sequence, leaving its zero point invariant. Second, the conversion of accretion rate to SFR is materialized through gas density, not gas mass. Although the model SFR is an increasing function of both gas mass fraction and gas density, only the gas densities are predicted to evolve significantly with redshift. Third, star formation is fueled by molecular gas. Since the molecular gas fraction increases monotonically with increasing gas density, the model predicts strong evolution in the molecular gas fractions, increasing by an order of magnitude from z=0 to $z^{\sim} 2$. On the other hand, the model predicts that the effective surface density of atomic gas is ~ 10 $Msun pc^{-2}$, independent of redshift, stellar mass or feedback. Our model suggests that the scatter in the SFR sequence reflects variations in the gas accretion history. The large scatter in halo spin contributes negligibly, because it scatters galaxies along the SFR sequence.

310

AGN, QSO, Blazars V Oral Session Room 607

310.01

The Connection Between Ultra-High-Energy Cosmic Rays and Fermi Gamma-Ray Sources Rodrigo Nemmen¹, T. Storchi-Bergmann², C. Bonnatto² ¹NASA GSFC, ²UFRGS, Brazil. 10:00 AM - 10:10 AM *Room 607* We analyze the correlation of the positions of gamma-ray sources in the Fermi Large Area Telescope First Source Catalog (1FGL) and the First LAT Active Galactic Nuclei (AGN) Catalog (1LAC) with the arrival directions of ultra-high-energy cosmic rays (UHECRs) observed with the Pierre Auger Observatory, in

directions of ultra-high-energy cosmic rays (UHECRs) observed with the Pierre Auger Observatory, in order to investigate the origin of UHECRs. We find that Galactic sources and blazars identified in the 1FGL are not significantly correlated with UHECRs, while the 1LAC sources display a mild correlation (2.6sigma level) on an ~2.4deg angular scale. When selecting only the 1LAC AGNs closer than 200 Mpc, we find a strong association (5.4sigma) between their positions and the directions of UHECRs on an ~17deg angular scale; the probability of the observed configuration being due to an isotropic flux of cosmic rays is 5E-8. There is also a 5sigma correlation with nearby 1LAC sources on an 6.5deg scale. We identify 7 ``gamma-ray loud'' AGNs which are associated with UHECRs within ~17deg and are likely candidates for the production sites of UHECRs: Centaurus A, NGC 4945, ESO 323-G77, 4C+04.77, NGC 1218, RX J0008.0+1450 and NGC 253. We interpret these results as providing additional support to the hypothesis of the origin of UHECRs in nearby extragalactic objects. As the angular scales of the correlations are large, we discuss the possibility that intervening magnetic fields might be considerably deflecting the trajectories of the particles on their way to Earth.

310.02 Gravitational Microlensing as a probe of Quasar Structure David Floyd¹

¹University of Melbourne, Australia. 10:10 AM - 10:20 AM

Room 607

Gravitational microlensing provides information at the micro-to-nano arcsecond scale necessary to probe the structure of the central engine of quasars. We can now determine the radius of the broad line emitting regions, and measure the temperature profile of the continuum emitting region using single-epoch observations. I will present X-shooter spectroscopy that provides new insight into the accretion mechanism, and the structure of the broad line region.

310.03

Multi-epoch Circular Polarization Of The MOJAVE Sample

Daniel C. Homan¹, M. L. Lister², MOJAVE Collaboration ¹Denison Univ., ²Purdue Univ..

10:20 AM - 10:30 AM

Room 607

We present multi-epoch circular polarization results from the MOJAVE-I sample. MOJAVE stands for Monitoring Of Jets in AGN with VLBA Experiments and is an ongoing program using the NRAO's Very Long Baseline Array (VLBA) to monitor the structure and polarization of a flux-density limited sample of extra-galactic radio jets at 15 GHz. We discuss the variability of circularly polarized emission from the first four years of the MOJAVE monitoring from mid-2002 through the end of 2005, spanning at least four epochs on each of the 133 sources in the original MOJAVE-I sample. Of 50 sources with multi-epoch circular polarization measurements at the >= 2 sigma level, we find only 2 sources that showed a change in observed sign of circular polarization during this time period. We discuss the implications of this apparent sign stability for the jet magnetic field.

This work has been supported by grants from the National Science Foundation (AST-0707693 and AST-0807860) and Research Corporation. The National Radio Astronomy Observatory, a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

310.04

A Unique Merging Pair among Luminous Binary Quasars: SDSS J1254+0846

Paul J. Green¹, A. D. Myers², W. A. Barkhouse³, J. S. Mulchaey⁴, V. N. Bennert⁵, T. J. Cox⁶, T. L. Aldcroft¹, J. M. Wrobel⁷

¹Harvard-Smithsonian CfA, ²UIUC, ³University of North Dakota, ⁴The Observatories of the Carnegie Institution for Science, ⁵UCSB, ⁶The Observatories of the Carnegie Institution for Science,, ⁷National Radio Astronomy Observatory.

10:40 AM - 10:50 AM

Room 607

SDSS J1254+0846 is the first luminous, spatially resolved binary quasar that clearly inhabits an ongoing galaxy merger. These two luminous (z=0.44) radio quiet quasars, with a radial velocity difference of just 215 km/s, are separated on the sky by 21 kpc in a disturbed host galaxy merger showing broad, symmetrical tidal arm features spanning some 75 kpc at the quasars' redshift. Our semi-analytic modeling suggests that the system consists of two massive disk galaxies prograde to their mutual orbit, caught during the first passage of an active merger. This demonstrates rapid black hole growth during the early stages of a merger between galaxies with pre-existing bulges. Neither of the two luminous nuclei show significant instrinsic absorption by gas or dust in our optical or X-ray observations,

illustrating that not all merging quasars will be in an obscured, ultraluminous phase. We find that the Eddington ratio for the fainter component B is rather normal, while for the A component it is quite high compared to quasars of similar luminosity and redshift, possibly evidence for strong merger-triggered accretion. More such mergers should be identifiable at higher redshifts using binary quasars as tracers. We further present Chandra imaging results for a sample of 14 quasars in spatially-resolved pairs. The pairs were all targeted as part of a complete sample of binary quasar candidates with small transverse separations drawn from SDSS DR6 photometry.

310.05

Keck LGS AO Imaging of QSOs with Double-Peaked or Offset Narrow Lines: Are They Signs of Potential Black Hole Mergers?

Rosalie C. McGurk¹, D. J. Rosario¹, C. E. Max¹, G. A. Shields², K. L. Smith² ¹University of California Santa Cruz, ²University of Texas Austin.

10:50 AM - 11:00 AM

Room 607

Hierarchical merging of smaller structures into larger ones is fundamental to galaxy evolution in ACDM cosmologies. The M_{bh} sigma relation suggests that when galaxies merge, their central supermassive black holes merge and grow as well. Using spectroscopic surveys such as SDSS and DEEP, candidates for galaxies containing two active black holes or an offset black hole have been identified by double-peaked or offset narrow emission lines. However it is not yet known whether these galaxies correspond to systems in which there are actually double supermassive black holes. With the Keck 2 Laser Guide Star Adaptive Optics system and the NIRC2 camera, we have obtained high spatial resolution near-infrared images of spectroscopically identified candidate galaxies that may contain two supermassive black holes. In our sample of 24 galaxies to date, approximately half are in close mergers, have close companion galaxies, and/or show clearly disturbed morphologies. We discuss the implications of our observations for the fueling of merging supermassive black holes as well as for the relationship between QSO activity and major mergers.

Most of the data presented herein were obtained at the W. M. Keck Observatory, which is operated as a scientific partnership among the California Institute of Technology, the University of California, and the National Aeronautics and Space Administration.

310.06

LBQS 0103-2753: A Binary QSO In A Major Merge

Gregory A. Shields¹, D. J. Rosario², V. Junkkarinen³, E. W. Bonning⁴, S. C. Chapman⁵, T. Chiba⁴ ¹Univ. of Texas, ²Max Planck Inst., Germany, ³UCSD, ⁴Yale Univ., ⁵Univ. of Cambridge, United Kingdom. 11:00 AM - 11:10 AM

Room 607

LBQS 0103-27 is binary QSO at z = 0.85 with a component separation of 2 kpc, one of the closest spacings known (Junkkarinen et al. 2001, ApJ 549, L155). One component is a BAL QSO. We present imaging in two colors with the Advanced Camera for Surveys (ACS) on the Hubble Space Telescope. The images reveal the host galaxy and a prominent tidal arm on a scale of 10 kpc, confirming that the object involves a major merger in progress. We also present spectra obtained with STIS on HST and with UKIRT. The Halpha emission line confirms the redshift agreement of the two components. We discuss LBQS in the context of other binary QSOs and implications for fueling of black holes during galaxy mergers.

310.07

Discovery of a Population of Close Binary AGN: Observing the Hierarchical Assembly of Supermassive Black Holes

Stanislav G. Djorgovski¹, H. Fu¹, A. Myers², L. Yan³, A. Stockton⁴

¹Caltech, ²UIUC, ³IPAC, ⁴Univ. of Hawaii.

11:10 AM - 11:20 AM

Room 607

Hierarchial structure formation predicts that as galaxies merge, so will their ubiquitous central supermassive black holes (SMBH), and thus binary SMBHs should be fairly common. Yet until recently, very few such cases were known, mostly as serendipitous, heterogeneous detections. We initiated a survey for close binary AGN, using diffraction-limited LGS AO imaging with the Keck telescope. The target sample is selected from a sample of SDSS AGN whose spectra display double narrow [O III] emission lines, possibly indicative of close binary AGN. A subset of the apparent double systems is then followed up by LGS AO IFU spectroscopy, in order to establish their physical nature. In an initial sample of 50 targets, we discovered 16 apparent close binary AGN. A subset of these has been followed by IFU spectroscopy, which indicates that the gas is indeed ionized by AGN. Thus, we have established the existence of a population of close binary SMBH in the ongoing merger systems. We find that the fraction of apparent SMBH binaries increases with redshift, in a way which is consistent with the observed galaxy merger fraction, as expected from the hierarchical assembly picture. We also find that the resolved binary SMBH systems represent outliers in the observed $M_{BH} - \sigma$ relation. Thus, pre-merger SMBH binaries can account for at least some of the observed scatter of this relation, which is used as one of the empirical constraints for the models of AGN feedback and co-evolution of galaxies and their SMBHs.

310.08

Broad H-beta Reverberation In The Kepler-field AGN Zw 229-015

Aaron J. Barth¹, M. L. Nguyen¹, M. A. Malkan², V. Gorjian³, A. V. Filippenko⁴, W. Li⁴, M. D. Joner⁵ ¹UC Irvine, ²UCLA, ³JPL, ⁴UC Berkeley, ⁵Brigham Young University. 11:20 AM - 11:30 AM

11:20 AIVI - 11:30

Room 607

Zw 229-015 is a low-redshift (z=0.028) Seyfert 1 galaxy in the Kepler field, and is one of the brightest active galaxies being monitored by the Kepler mission. In order to determine the black hole mass in this object from H-beta reverberation mapping, we have obtained nightly spectroscopic observations with the Kast Spectrograph at the Lick 3-m telescope during the dark runs beginning in June 2010, with 38 epochs of data in hand as of late September. We have also obtained nightly V-band imaging with the Katzman Automatic Imaging Telescope at Lick Observatory and with the 0.9-m telescope at the Brigham Young University West Mountain Observatory. We detect strong variability in the source, which exhibited more than a factor of 2 change in broad H-beta flux during the monitoring period. We will present measurements of the H-beta lag relative to the continuum variations, and an estimate of the black hole mass based on the H-beta lag and line width. As a Kepler target, Zw 229-015 will eventually have one of the highest-quality optical light curves ever measured for any active galaxy, and the black hole mass determined from reverberation mapping will serve as a benchmark for testing relationships between black hole mass and continuum variability characteristics in active galactic nuclei.

311 *Stellar Evolution, Stellar Populations and Variable Stars* Oral Session *Room 606*

311.01

Thermohaline Mixing at Low Prandtl Numbers

Adrienne Traxler¹, P. Garaud¹, S. Stellmach²

¹UC, Santa Cruz, ²Westfälische Wilhelms-Universität Münster, Germany.

10:00 AM - 10:10 AM

Room 606

Thermohaline mixing has been invoked in stellar contexts to explain the transport of heavy elements across stably stratified regions. Although studied in the Earth's oceans as "salt fingering," extrapolation of the process to the astrophysical regime is problematic due to the extreme values of the governing parameters, in particular the Prandtl number (Pr) and the ratio of the compositional and thermal diffusivities (τ). The current standard approach for modeling thermohaline mixing relies on the finger aspect ratio, and in particular requires tall, thin fingers to explain the observed mixing. We present the results of a set of low-Pr, low- τ , three-dimensional direct numerical simulations of

fingering convection. Rather than assuming a dependence on finger aspect ratio, we find heat and compositional transport laws as a function of the background stratification. These laws scale smoothly with decreasing Pr and τ , making it possible for the first time to reliably parameterize the effect of thermohaline mixing in the astrophysical regime.

The authors gratefully acknowledge funding from the National Science Foundation and the NASA Solar and Heliospheric Program.

311.02D

Chemical Tagging of Solar Neighborhood Kinematic Streams

Christopher Stringer¹, B. W. Carney¹

¹UNC - Chapel Hill.

10:10 AM - 10:30 AM

Room 606

We present high resolution spectra measurements for Lanthanum, Europium, and Iron in 700 stars in the solar neighborhood. The bulk of our data are planet search spectra taken with HIRES on the Keck I telescope at R=50,000. A small subset of kinematically selected stars were observed on the Harlan J. Smith Telescope at McDonald Observatory at R=60,000 and S/N~100 at the 3988 Å Lanthanum line and S/N~250 around 5240 Å near the Iron lines. Statistical analyses of stellar kinematics in the solar neighborhood reveal much kinematic substructure in the disk, though it is not readily apparent whether this substructure is extragalactic or dynamical in origin. Much of the substructure can be quickly identified as well known moving groups of stars such as the Hercules, Sirius, and Hyades stellar streams. Additionally, our subset of kinematically selected stars observed at McDonald Observatory are members of a stellar stream putatively identified by Amina Helmi as part of a merger remnant. Taking advantage of a large data set and a homogenous spectral analysis, we apply a Kolmogorov-Smirnov hypothesis test to investigate the possibility that these kinematic structures are chemically distinct from the Galactic Disk.

311.03D

RR Lyrae in LMC Globular Clusters: Insights into the Oosterhoff Phenomenon and Milky Way Formation

Charles A. Kuehn, III¹, H. A. Smith¹, M. Catelan², L. Taylor³, R. E. McClellan⁴, K. Looper¹, N. DeLee⁵, B. J. Pritzl⁶

¹Michigan State University, ²Pontificia Universidad Católica de Chile, Chile, ³Transylvania University, ⁴University of Illinois at Urbana-Champaign, ⁵University of Florida, ⁶University of Wisconsin Oskosh. 10:30 AM - 10:50 AM

Room 606

We present results from a study of RR Lyrae stars in five globular clusters located in the Large Magellanic Cloud. The goal of this study was to look at the behavior and properties of RR Lyrae stars in Oosterhoffintermediate globular clusters and compare them to RR Lyrae in Oosterhoff I and II clusters. New BVI photometric observations of these clusters were obtained with the SMARTS consortium telescopes and with the SOAR 4-meter telescope. We present light curves and Fourier properties for the RR Lyrae stars in our study as well as physical properties for these stars derived from their Fourier parameters. We compare these physical properties to those of RR Lyrae in Milky Way halo globular clusters and discuss implications for Milky Way halo formation.

311.04

First Results from the Carnegie Hubble Project - Cepheids in the LMC

Victoria Scowcroft¹, J. Rigby², B. Madore¹, W. Freedman¹, A. Monson¹, S. E. Persson¹, M. Seibert¹, P. Stetson³, L. Sturch⁴

¹Carnegie Institution for Science, ²Goddard Space Flight Center, ³Dominion Astrophysical Observatory, Canada, ⁴Boston University.

10:50 AM - 11:00 AM

Room 606

The Carnegie Hubble Project is a Warm Spitzer Legacy mission, and has the aim of measuring H_0 to an accuracy of 2%. The IRAC band Cepheid period--luminosity relations will be calibrated using Galactic and LMC samples, which were selected for their well--measured distances in the Galactic case, and to be free of crowding in the LMC case. The relations will then be used to obtain distances to a selection of galxies in our local group and beyond. The distance scale will be further extended using the Tully--Fisher relation to obtain distances to supernova--host galaxies and more distant galaxy clusters. The first step in this process is to calibrate the Cepheid period--luminosity relation in the IRAC bands, using Galactic and LMC Cepheids. I will discuss the calibration of the relation in the LMC, and demonstrate how the excellent quality data that Spitzer has provided has enabled us to not only calibrate the PL relation, but to study the structure of the LMC itself.

311.05

Survey Of Cepheids In M33: On The Origin Of The Distance Modulus Grandient

Anne Pellerin¹, L. M. Macri¹

¹Texas A&M University.

11:00 AM - 11:10 AM

Room 606

We are conducting a detailed photometric survey of variable stars in the nearby galaxy M33 using ground-based B, V, I images. The data cover the entire galactic disk and were collected over a 7 years period. Our work combines the datasets from the DIRECT project as well as more recent data from the WIYN 3.5m telescope. Here we present the detailed stellar photometric catalog in M33, with emphasis on more than 650 confirmed Cepheid stars for which we have fitted light curves. This increases the

number of confirmed M33 Cepheids by a factor of almost three.

Based on our Cepheid sample we have studied the impact of stellar crowding and blending on the Cepheid distance determination in M33, and more specifically on the search for the metallicity effect on distance modulus. Combining our ground-based data to archival images from the Hubble Space Telescope, we show that stellar crowding and blending is contributing significantly, if not entirely, to the radial distance modulus gradient observed in M33, which was previously associated to a metallicity effect. Our results suggest that the distance modulus variation with metallicity, and measured in other nearby galaxies, is probably flatter than reported in previous works.

311.06

Rossi X-ray Timing Explorer Proportional Counter Array Observations of the 35-day Cycle of Hercules X-1

Denis A. Leahy¹, C. D. Igna¹

¹Univ. of Calgary, Canada. 11:10 AM - 11:20 AM

11:10 AIVI - 11:20 AIV

Room 606

The X-ray binary Hercules X-1/HZ Her (or Her X-1) is perhaps the best-known of the set of X-ray binaries with long term periodicities. Its 35-day cycle consists of a regular sequence of high, low and short-high states. The cause of the cycle has been established to be changing obscuration of the line-of-sight to the neutron star by a warped accretion disk which precesses in the binary frame. In this study, we use X-ray observations of Her X-1 taken over a period of more than 10 years with the Proportional Counter Array (PCA) instrument of the Rossi X-ray Timing Explorer (RXTE) satellite. With 35-day phase determined by our previous study using RXTE All Sky Monitor data, we study the nature of the changes that occur over 35-day cycle that can be seen in detail with RXTE/PCA data. This includes overall spectral changes and the timing of pre-eclipse, post-eclipse and anomalous dips. Various models for the dips are assessed in the light of the new information.

This work funded by the Natural Sciences and Engineering Research Council of Canada.

312

Nearby Galaxy Clusters, Groups, and Ellipticals Oral Session *Room 604*

312.01D The Virgo Cluster Through The AGES Rhys Taylor¹

¹Arecibo Observatory. 10:00 AM - 10:20 AM Room 604

I present results from the neutral hydrogen Arecibo Galaxy Environment Survey (AGES) for two regions in the Virgo Cluster, covering 15 square degrees to a sensitivity of 0.6 mJy/beam. 73 objects are detected within the cluster, with 109 detections in the background. The majority of the cluster detections are associated with galaxies previously identified in the optical Virgo Cluster Catalogue, but nearly 30% of the cluster detections are new objects below the VCC completeness limit. No definite optically dark galaxies are identified, however 4 intriguing candidates are reported. All have possible optical counterparts but these are extremely faint, and their HI velocity widths appear inconsistent for such objects when compared to the more certain associations. I discuss the likelihood that these are really dark galaxies.

Cluster galaxies are found to be significantly HI deficient but it is not clear where their missing gas has

gone. An automated algorithm is described to try to recover faint extended HI features, but no detections are made. I assess whether this implies the cluster environment inhibits the production and survival of such features, or whether it is due to insufficient sensitivity.

A small fraction (~10%) of the early-type galaxies identified in the VCC are detected in HI. Evidence that some of these are morphologically evolving via gas loss, while others are recent additions to the cluster as yet unaffected by their new environment, is discussed.

This research was funded by the Science and Technology Facilities Council of the U.K.

312.02D

Ages of Globular Cluster Systems and the Relation to Galaxy Morphology

Ana Chies Santos¹, S. S. Larsen¹, H. Kuntschner², P. Anders¹, E. M. Wehner¹, J. Strader³, J. P. Brodie⁴, J. F. C. Santos Jr.⁵

¹Astronomical Institute Utrecht, Netherlands, ²ESO, Germany, ³CfA, ⁴UCO/Lick Observatory, ⁵UFMG, Brazil.

10:20 AM - 10:40 AM

Room 604

We have investigated the age distributions of GC systems in 14 early-type galaxies using homogeneously derived K-band LIRIS/WHT and archival g and z ACS/HST photometry. A relative comparison between the different GC systems was performed where relative age differences were quantified. We report the finding of a correlation between the morphological type of a galaxy and mean relative GC ages. Galaxies with simple morphology such as EOs, E1s and E2s seem to have genuinely old clusters whereas SOs have younger GC systems. Surprisingly, this appears to be driven by the more metal-poor clusters. We suggest that E type galaxies assembled most of their GCs in a shorter and earlier period than SO type galaxies. The latter galaxy type, seems to have a more extended period of GC formation/assembly.

312.03

Investigating the Cores of Early-Type Galaxies Using the ACS Virgo and Fornax Cluster Surveys

Lisa Glass¹, L. Ferrarese¹, P. Côté¹, A. Jordán², E. Peng³, J. Blakeslee¹, C. Chen⁴, L. Infante², S. Mei⁵, J. Tonry⁶, M. J. West⁷

¹*Herzberg Institute of Astrophysics, Canada,* ²*Departamento de Astronomia y Astrofisica, Chile,* ³*Peking University, China,* ⁴*National Central University, Taiwan,* ⁵*Observatoire de Paris, France,* ⁶*Institute for Astronomy,* ⁷*ESO, Chile.*

10:40 AM - 10:50 AM

Room 604

Understanding the processes that shape and influence the centers of galaxies is crucial to understanding galaxies as a whole. In particular, data suggests nuclear star clusters are three times more common than previously thought and there is evidence to suggest that they may be the low-mass analogues to the supermassive black holes found in more luminous galaxies. My research focuses on the cores of early-type galaxies and how they relate, influence, and respond to processes occurring in the rest of the galaxy. I will present new results from the ACS Virgo and Fornax Cluster Surveys that shed light on these questions.

The authors gratefully acknowledge support from NSERC though the Discovery and Postgraduate Scholarship programs, as well as from the University of Victoria through their fellowship program.

312.04

Anatomy of an Early-type Minor Merger: Modelling the Young Stars and Their Kinematics in NGC 4150 Using The Wide Field Camera 3 (WFC3) snd SAURON

Sugata Kaviraj¹, M. Crockett², M. Cappellari², R. McDermid³, L. Young⁴, M. Bureau², J. Silk², R. W. O'Connell⁵, WFC3 SOC

¹Imperial College London and University of Oxford, United Kingdom, ²University of Oxford, United Kingdom, ³Gemini Observatory, ⁴New Mexico Tech, ⁵University of Virginia.

10:50 AM - 11:00 AM

Room 604

Recent studies using ultraviolet (UV) and optical data have demonstrated the widespread presence of recent star formation in early-type galaxies (ETGs) since z~1. This star formation, plausibly driven by the accretion of gas-rich satellites, contributes a few percent in mass to individual ETGs. Combining the unprecedented UV/optical field-of-view and sensitivity of the WFC3 with integral field spectroscopy from SAURON, we perform a detailed, spatially-resolved analysis of young stars and their kinematics in the lenticular galaxy NGC 4150, a suspected recent merger remnant. A 'pixel-by-pixel' analysis in 5 WFC3 filters, spanning UV to i-band, reveals a central 0.9 Gyr old young stellar population, with a median metallicity of 0.5 solar, that contributes around 3% of the stellar mass. A lack of Halpha emission indicates that there is no ongoing star formation in this galaxy. Assuming that the metallicity of the young stars traces the gas-phase metallicity of the satellite that fuels the star formation, we estimate the mass ratio of the merger to be ~1:15. The young stars coincide spatially with a kinematicallydecoupled core (KDC), observed in the stellar kinematics. A dynamical model for the KDC, assuming that it forms from the young stars, reproduces all the SAURON kinematic observables with high precision, including a double peak in velocity dispersion, the core stellar velocities and the velocity RMS. In summary, NGC 4150 is a post-starburst remnant, of a minor merger with a mass ratio of 1:15, where the young stars reside in a central KDC containing around 3% of the total stellar mass. This study demonstrates the potentially powerful combination of high-resolution imaging and integral-field units on future telescopes.

Based on Early Release Science observations by the WFC3 Scientific Oversight Committee. We are grateful to the Director of the Space Telescope Science Institute for awarding Director's Discretionary time for this program.

312.05

Compact Galaxy Groups: A Multi-wavelength Perspective Into Galaxy Evolution Iraklis Konstantopoulos¹, HCG Collaboration

¹Penn State University.

11:00 AM - 11:10 AM

Room 604

Galaxies are seldom found in isolation. As a small unit of large clusters, individual members are subject to the volition of their groupings and evolve most commonly through interactions and mergers. In the parameter-space between too many friends and none at all lie compact galaxy groups. The ones classified by Hickson (1982; Hickson compact groups, or HCGs) share the distinctive characteristics of low membership, isolation and high density. They exhibit low velocity dispersions, which which lead to prolonged interactions, when such events occur, or quasi-secular evolution, when they do not. They are also HI-deficient, to a very intriguing extent.

I will be discussing multi-wavelength observations of a sample of 12 HCGs in the context of galaxy evolution in general. For example, in HCG 7 we observed the strengthening of interactions due to the complexity of the tidal field, in a system that is likely headed toward a dry merger. In the low mass grouping of HCG 31 we recorded morphological transformation reminiscent

of the intermediate redshift universe, with multiple simultaneous

interactions leading to the build-up of a gaseous intra-group medium. These results, along with many more, allow us to examine the overall themes that arise from the study of the aforementioned dozen: the usage of gas; the possibility of rapid morphological transformation of compact group galaxies; and the role of groups as the tail end of the galaxy clustering N-distribution.

313 *Cosmic Microwave Background* Oral Session *Room 401*

313.01D Is There Any Real Observational Contradictoty To The Lcdm Model? Yin-Zhe Ma¹

¹University of Cambridge, United Kingdom. 10:00 AM - 10:20 AM

Room 401

313.02

The Atacama Cosmology Telescope: Power Spectrum and Gravitational Lensing Sudeep Das^1

¹University of California, Berkeley.

10:20 AM - 10:30 AM

Room 401

Arcminute resolution observations of the mm-wave sky are changing our view of the cosmic microwave background (CMB) in a fundamental way. Together with mapping out the acoustic features on the Silk damping tail of CMB, data from the Atacama Cosmology Telescope (ACT) are providing new insights into secondary CMB anisotropies and extragalactic point source populations that dominate the scene at small angular scales. I will describe the angular power spectrum measurements from ACT, and an ongoing search for the gravitational lensing signal in ACT maps.

313.03

Cosmological Parameters from the Atacama Cosmology Telescope

Jonathan L. Sievers¹, Atacama Cosmology Telescope Collaboration

¹CITA, Canada.

10:30 AM - 10:40 AM

Room 401

The Atacama Cosmology Telescope (ACT) has surveyed hundreds of square degrees with arcminute resolution at mm wavelengths. Multi-frequency ACT observations of the Cosmic Microwave Background (CMB) have shed light on several fundamental cosmological parameters. We present the ACT constraints on parameters such as the number of relativistic species, the primordial tensor-to-scalar ratio, the spectral index of adiabatic fluctuations, the integrated power from the Sunyaev-Zeldovich effect in galaxy clusters, and structure formation from a sub-dominant cosmic string component.

313.04 Fluctuation Analysis of the Point Source Population in Microwave Background Maps Kevin Huffenberger¹

¹University of Miami. 10:40 AM - 10:50 AM

Room 401

Fluctuation analysis of maps using the one-point distribution function is a standard technique in sub-mm astronomy to explore the number counts of source populations. Here we describe using these methods to constrain the residual point source signal in combinations of microwave frequency maps that subtract out the CMB. This complements the usual power spectrum-based methods for characterizing these sources. We apply the method to WMAP 7-year data to constrain the source population and the frequency dependence of sources at WMAP frequencies, and discuss applications to other experiments.

313.05

Current Status of the PIPER Experiment

Bradley Johnson¹, P. Ade², D. Benford¹, C. Bennett³, D. Chuss¹, J. Dotson⁴, J. Eimer³, D. Fixsen¹, M. Halpern⁵, G. Hilton⁶, J. Hinderks¹, G. Hinshaw¹, K. Irwin⁶, N. Jethava¹, C. Jhabvala¹, A. Kogut¹, J. Lazear³, L. Lowe¹, T. Miller¹, P. Mirel¹, H. Moseley¹, S. Rodriguez¹, K. Rostem¹, E. Sharp¹, J. Staguhn¹, C. Tucker², G. Voellmer¹, E. Wollack¹, L. Zeng³

¹NASA/GSFC, ²Cardiff University, United Kingdom, ³Johns Hopkins University, ⁴NASA/Ames, ⁵University of British Columbia, Canada, ⁶NIST.

10:50 AM - 11:00 AM

Room 401

The Primordial Inflation Polarization Explorer (PIPER) is a balloon-borne instrument to measure the polarization of the cosmic microwave background in search of the expected signature of primordial gravity waves excited during an inflationary epoch shortly after the Big Bang. PIPER consists of two coaligned telescopes, one sensitive to the Q Stokes parameter and the other to U. Sky signals will be detected with 5120 transition edge sensor (TES) bolometers distributed in four rectangular close-packed arrays maintained at 100 mK. To maximize the sensitivity of the instrument, both telescopes are mounted within a single open bucket dewar and are maintained at 1.5 K throughout flight, with no ambient-temperature windows between the sky and the detectors. To mitigate the effects of systematic errors, the polarized sky signals will be modulated using a variable-delay polarization modulator. PIPER will observe at frequencies 200, 270, 350, and 600 GHz to separate the CMB from polarized dust emission within the Galaxy. A series of flights alternating between northern and southern hemisphere launch sites will produce nearly full-sky maps in Stokes I, Q, U, and V. I will discuss the current status and potential science returns from the PIPER project.

Wednesday, January 12, 2011, 11:40 AM - 12:30 PM

314 Heinemann Prize: The Inner Space/Outer Space Connections: Dark Matter, Dark Energy, Inflation and All That

Invited Session Ballroom 6AB

314.01

The Inner Space/Outer Space Connections: Dark Matter, Dark Energy, Inflation and All That Edward W. Kolb, Jr.¹, M. S. Turner¹

¹University of Chicago. Ballroom 6AB

The deep connections between the very big and the very small have changed the way we think about the Universe and transformed cosmology. We will discuss the three pillars of the consensus cosmology - dark matter, dark energy and inflation -- and their connections to fundamental physics and speculate about "all that".

Wednesday, January 12, 2011, 2:00 PM - 3:30 PM

317

Observing with ALMA Special Session Ballroom 6A

317.01

The North American ALMA Science Center, NAASC Carol J. Lonsdale¹, NAASC Team ¹*NRAO.* 2:00 PM - 2:15 PM *Ballroom 6A* The North American ALMA Science Center at the NRAO in Charlottesville will provide user support for ALMA in North America. We will provide a brief overview of the NAASC services for the community for the early phases of ALMA operations.

317.02

ALMA - The March to Early Science and Beyond Alwyn Wootten¹ ¹NRAQ.

2:15 PM - 2:30 PM Ballroom 6A

The Atacama Large Millimeter/submillimeter Array is rapidly proceeding through its commissioning stages in Chile. Tests at the atmospherically superb 5050m Array Operations Site and readiness reviews held during the Fall of 2010 will result in a decision to issue a call for proposals to use the instrument during its 'Early Science' phase. At the beginning of Early Science, projected for later in 2011, 16 antennas of the final 66 will stand ready to produce the deepest integrations ever achieved in the cool thermal spectral region. The array will be equipped with at least three of its eventual complement of ten receivers operating over a decade of bandwidth from 3.6mm to 0.42mm. At this point, its sensitivity will be on the order of 0.5mJy in a minute's integration. Operating at this stage baselines of at least .25km, ALMA will provide a beam as small as 0".3 on the little-explored southern skies from its Chilean site near the Tropic of Capricorn. By one year later, the array will have grown to more than fifty antennas; at the

second call for proposals the array will reach 0.2 mJy in a minute and baselines will extend to the full set of array configurations, effectively about 14 km. Observations which will be made possible by these transformative capabilities will be presented.

317.03

Tools for the ALMA Users for Early Science

Kartik Sheth¹, NAASC Team ¹National Radio Astronomy Observatory. 2:30 PM - 2:45 PM Ballroom 6A

The first opportunity to use ALMA will be announced shortly in a Early Science Call for Proposals. In this talk, we provide an overview of the Phase I user tools (ALMA Observing Tool, ALMA Sensitivity Calculator, SIMData and Splatalogue) needed for the North American community to plan and propose for observing time with ALMA. We will also provide a brief overview of the phase II tools (Project Tracker, ALMA Science Archive) that will be used by PIs of approved programs to execute their science programs. After observations are complete, users will likely use the ALMA Science Archive and CASA to further examine the data and data products, which will be described briefly.

317.04

ALMA from the User Perspective: Galactic

David J. Wilner¹ ¹*Harvard-Smithsonian, CfA.*

2:45 PM - 3:00 PM

Ballroom 6A

ALMA will be "transformative" for studies of cool components of the Galaxy, in particular the molecular gas and dust in the immediate vicinity of young or evolved stars where arcsecond or higher resolution will be especially valuable to probe structure, dynamics, and chemistry. At the start of Early Science scheduled for 2011, the subset of available ALMA antennas already will provide spectral line and continuum sensitivity and imaging capabilities that exceed any of the existing millimeter arrays. Using examples from star-forming regions and circumstellar disks, I will illustrate how a prospective ALMA user can realize the fantastic potential of this new facility in the Early Science stage and beyond.

317.05

ALMA does Galaxies! A User's Perspective on Early Science Jean Turner¹

¹UCLA. 3:00 PM - 3:15 PM Ballroom 6A

Star formation and its regulation, rotation curves, dust and gas masses, gas dynamics and secular evolution of galaxies, interactions and mergers, cosmic pyrotechnics, and monster-feeding are among the many topics that can be studied with ALMA. We talk about many of the explorations of the extragalactic world that are possible with this awesome instrument in its Early Science incarnation, and discuss how these first generation studies with Early-ALMA compare to what will eventually be possible with the full array.

317.06 The North American ALMA Science Center: Canadian Roles James Di Francesco¹

¹NRC-Canada, Canada. 3:15 PM - 3:30 PM Ballroom 6A

In partnership with NRAO, North American regional support for ALMA operations will be provided also by the National Research Council of Canada though its Herzberg Institute of Astrophysics (NRC-HIA) in Victoria, BC. In this short presentation, we describe the roles the Millimeter Astronomy Group of NRC-HIA will play in providing user support, documentation and observers for ALMA.

318

Exoplanet Detection: Many Techniques Oral Session Ballroom 6B

318.01

The Microlensing Planet Search Program of the WFIRST Mission David P. Bennett¹

¹Univ. of Notre Dame. 2:00 PM - 2:10 PM Ballroom 6B

The recently Decadal Survey report, "New Worlds, New Horizons in Astronomy and Astrophysics" recommends a new mission called WFIRST as its top ranked large space mission for the next decade. The WFIRST mission is to have two major science programs that will drive the design requirements: a dark energy program and a microlensing planet search program. WFIRST's microlensing planet search program will provide a statistical census of exoplanets with masses greater than one tenth of an Earth mass and orbital separations ranging from 0.5AU to infinity. This includes analogs to all the Solar System's planets except for Mercury, as well as most types of planets predicted by planet formation theories. In combination with Kepler's census of planets in shorter period orbits, WFIRST's planet search program will provide a complete statistical census of the planets that populate our Galaxy.

318.02D

Optimal Estimation for Exoplanet Data Streams

Dmitry Savransky¹, N. Kasdin¹

¹Princeton University.

2:10 PM - 2:30 PM

Ballroom 6B

The pace of exoplanet discovery has been steadily accelerating. New detection methods are progressively mapping out more and more of the parameter space of planetary and orbital characteristics. Early results from Kepler and plans for future ground-based surveys indicate that future exoplanet databases will provide us with detailed statistics on many different planet types. Given the expectation that future databases will include many different observations of the same targets, it is useful to consider how these varying data streams may interact. We propose that any data gathered about an extra-solar planetary system (exosystem) may be treated as a partial observation of a Markov process, governed by the known laws of gravity and optics. As such, any exoplanet observation should be useful given that it is possible to relate it to a common parameter set, and it is possible to accurately quantify the error of the measurement. We present a method for incorporating any observation that meets these qualifications into a common exosystem model, based on estimation theory. A
standardized parameter set is defined, with priors calculated from known exoplanet statistics, and multiple methods are evaluated for calculating posterior parameter distributions given new observations. We present specific implementations for direct imaging, radial velocity and astrometry observations, as well as for transit photometry.

318.03

The Prospects for Finding Nearby Planets with Mesolensing Rosanne Di Stefano $^{\rm 1}$

¹*Harvard-Smithsonian CfA.* 2:30 PM - 2:40 PM

Ballroom 6B

Microlensing events can identify planetary systems located at great distances from us, in the Galactic Bulge, for example. It is also possible for lensing to identify planetary systems located within a kpc. In this talk we will sketch the signatures expected when the lenses are nearby (i.e., mesolenses) and will consider how the information derived from lensing can be sometimes be combined with transit or radial velocity studies.

318.04

Direct Detection of Exoplanets with Polarimetry

Sloane Wiktorowicz¹, J. R. Graham²

¹University of California, Berkeley, ²University of California, Berkeley; Dunlap Institute for Astronomy and Astrophysics, University of Toronto.

2:40 PM - 2:50 PM

Ballroom 6B

The detection of scattered light from exoplanets gives direct access to physical conditions and composition of their atmospheres. Currently, most scattered light experiments focus on nearly edge-on, transiting systems. The temporal changes that occur during planetary occultations are used to suppress systematic errors, which would otherwise overwhelm the planetary signal. Linear polarimetry also has the potential to detect scattered light from exoplanets, because the polarization state of light scattered from a planetary atmosphere distinguishes it from both the direct light from the host star and thermal re-radiation from the planet. This scattered flux should be identifiable even in face-on systems, because both degree and position angle of polarization are modulated continuously throughout the orbit. We report on searches for exoplanetary scattered light using the POLISH2 polarimeter on the Lick 3-m telescope. This instrument has recently been upgraded with new detectors and a high-speed data acquisition system, which give a factor of ten improvement in precision better than one part per million on V < 9 stars, and it is ideally suited for direct detection of close-in exoplanets. This work was supported by a UC Lab Fees Research Grant and UCO/Lick Observatory.

318.05

Detection of Moons around Giant Extrasolar Planets

Dora Musielak¹, Z. E. Musielak¹

¹University of Texas at Arlington.

2:50 PM - 3:00 PM

Ballroom 6B

The fact that Jupiter's radio emission is affected by the presence of its moon Io has been know for many years and extensively studied both observationally and theoretically. Since Io moves inside the Jovian magnetic field, its motion produces currents along the field lines that connect the moon to the Jupiter's polar regions, where the radio emission is modulated by the currents. It has been suggested that such

modulation of planetary radio emission may reveal the presence of moons around giant planets in extrasolar planetary system. With the first indirect observational evidence for extrasolar planetary magnetic fields, and with the promise of detecting more such cases by the upcoming new observations, we seriously consider the idea and determine the required physical conditions for such detection to take place. The results of our study will be used to select the most promising candidates for detection of moons around giant planets in currently known extrasolar planetary systems.

319

The Sun, the Earth & Astrobiology Oral Session *Ballroom 6C*

319.01

Elemental Abundance Mapping for Determining Nearby Habitable Stellar Systems Natalie R. Hinkel¹, S. Schmidt¹, N. Tr'Ehnl¹, F. X. Timmes¹ ¹*Arizona State University.* 2:00 PM - 2:10 PM *Ballroom 6C* We present preliminary results from a compilation of abundance data for stars in the Catalog of Nearby Habitable Systems (Turnbull, M.C. and Tarter, J.C 2003, ApJS, 145, 181). "HabCat" contains a listing of star systems which conceivably have habitable planets and so our focus has been on those bio-essential elements, namely: C, N, O, Mg, S, and Ti. We have mapped the spectroscopically determined abundances in 3D and also 2D slices, for deterministic trends that occur both spatially and with regard to representative elements. These element abundance maps illustrate nucleosynthesis patterns within

500ly of the Sun which may include potential hosts to Earthlike planets.

319.02

Ultraviolet Observations of Solar Variability from the Solar Dynamics Observatory

Phillip C. Chamberlin¹, Solar Dynamics Observatory Team

¹NASA/GSFC. 2:10 PM - 2:20 PM

Ballroom 6C

The launch of the Solar Dynamics Observatory (SDO) in February 2010 allows for continuous ultraviolet observations of the Sun on all times scales from seconds to years. These variations in the solar plasma cause significant deviations in the Earth and space environments on similar time scales, such as affecting the atmospheric densities and composition of particular atoms, molecules, and ions in the atmospheres of the Earth and other planets. Presented and discussed will be examples of initial results using the data from SDO that show how we can trace the origins of solar activity from inside the Sun using different wavelengths, and therefore different temperatures, that cover the atmosphere and plasma temperature range of the solar atmosphere. The presentation will emphasize how the Solar Dynamics Observatory (SDO), the first satellite in NASA's Living with a Star program, is going to improve upon current observations and provide further insights into the variable Sun and its Heliospheric influence.

319.03 SDO-AIA DEM: Initial Results Joan T. Schmelz¹ ¹Univ. of Memphis.

2:20 PM - 2:30 PM

Ballroom 6C

The Atmospheric Imaging Assembly (AIA) aboard the Solar Dynamics Observatory has state-of-the-art spatial resolution and shows the most detailed images of coronal loops ever observed. The series of coronal filters peak at different temperatures, which span the range of active regions. These features represent a significant improvement over earlier coronal imagers and make AIA ideal for multi-thermal analysis. Here we targeted a 171-A coronal loop in AR 11092 observed by AIA on 2010 August 3. Isothermal analysis using the 171-to-193 ratio gave a temperature of Log T = 6.1, similar to the results of EIT and TRACE. Differential Emission Measure analysis, however, showed that the plasma was multithermal, not isothermal, with a distribution that peaked between Log T = 6.3 and 6.4. The result from the isothermal analysis, which is the average of the true plasma distribution weighted by the instrument response functions, appears to be deceptively low. These results have potentially serious implications: EIT and TRACE results, which use the same isothermal method, show substantially smaller temperature gradients than predicted by standard models for loops in hydrodynamic equilibrium and have been used as strong evidence in support of footpoint heating models. These implications may have to be re-examined in the wake of new results from AIA.

319.04

Is a High Mass Loss Rate for the Sun a Solution to the Faint Young Sun Paradox?

Christene R. Lynch¹, R. L. Mutel¹, K. G. Gayley¹

¹University of Iowa.

2:30 PM - 2:40 PM

Ballroom 6C

During the Archean eon (3.8 Ga) standard stellar evolution theory predicts a solar luminosity of only 75% of the present value; this luminosity predicts freezing surface temperatures on both early Earth and Mars. Yet geological evidence supports the existence of liquid water on these planets during this time. It has been suggested that the Sun had a higher mass and hence higher luminosity at early epochs, but lost mass through a much denser stellar wind. One test of this hypothesis would be detection of large mass loss rates from young solar analogs. However, such detections are difficult due to weak stellar winds and a multi-wavelength study may be necessary. An indirect method of studying these stellar winds and mass loss, involves the interaction of the wind with the interstellar medium (ISM). This interaction leads to Lyman- α absorption lines (aka hydrogen walls). In addition, radio observations of several young, nearby solar-like stars, using the Very Large Array (VLA), have lead to calculations for upper limits of mass loss from these stars. We will present results from a continuation of this latter approach using the Extended Very Large Array (EVLA) to observe the young, near-by solar analogs, π^{01} UMa and κ^{01} Cet.

319.05D

Terrestrial Effects of High Energy Cosmic Rays Dimitra ${\rm Atri}^1$

¹University of Kansas. 2:40 PM - 3:00 PM

Ballroom 6C

On geological timescales, the Earth is likely to be exposed to an increased flux of high energy cosmic rays (HECRs) from astrophysical sources such as nearby supernovae, gamma ray bursts or by galactic shocks. These high-energy particles strike the Earth's atmosphere initiating an extensive air shower. As the air shower propagates deeper, it ionizes the atmosphere by producing charged secondary particles. Increased ionization could lead to changes in atmospheric chemistry, resulting in ozone depletion. This could increase the flux of solar UVB radiation at the surface, which is potentially harmful to living organisms. Increased ionization affects the global electrical circuit can could possibly enhance the low-

altitude cloud formation rate. Secondary particles such as muons and thermal neutrons produced as a result of nuclear interactions are able to reach the ground, enhancing the biological radiation dose. The muon flux dominates radiation dose from cosmic rays causing DNA damage and increase in the mutation rates, which can have serious biological implications for terrestrial and sub-terrestrial life. This radiation dose is an important constraint on the habitability of a planet. Using CORSIKA, we perform massive computer simulations and construct lookup tables from 10 GeV - 1 PeV primaries (1 PeV - 0.1 ZeV in progress), which can be used to quantify these effects. These tables are freely available to the community and can be used for other studies, not necessarily relevant to Astrobiology. We use these tables to study the terrestrial implications of galactic shock generated by the infall of our galaxy toward the Virgo cluster. This could be a possible mechanism explaining the observed periodicity in biodiversity in paleobiology databases.

319.07

Terrestrial FeO Continuum Emission Observed in Sky Spectra

Tom G. Slanger¹, R. Melchiorri¹, D. V. Saran¹ ¹*SRI International.*

3:20 PM - 3:30 PM Ballroom 6C

The terrestrial continuum emission in the visible spectral region has often been studied by both astronomers and aeronomers, in order to clarify backgrounds and the nature of the emissions. New observations from the ESI spectrograph on the Keck II telescope, as well as from the OSIRIS/Odin spectrograph and orbiter, have established that a major component of the emission originates with the FeO molecule [Evans et al., 2010]. This quasi-continuum peaks at 5950 A and extends from 5000 A well into the infrared. The identity has been demonstrated by comparison with meteor trains and laboratory measurements [Jenniskens et al., 2000]. Early studies of the continuum show consistency with the FeO emission as presently observed [Gadsden and Marovich, 1973]. Analysis of spectra from Kitt Peak [Neugent and Massey, 2010] demonstrates the great similarity between FeO emission in a clean atmosphere and high pressure sodium lamp emission in a polluted atmosphere. This research was supported by NSF Aeronomy under Grant ATM-0637433

Evans, W.F.J., et al., Geophys. Res. Lett. [in press, 2010] Gadsden, M. and E. Marovich, J. Atm. Terr. Phys., 35, 1601-1614 [1973] Jenniskens, P., et al., Earth, Moon and Planets, 82-83, 429-434 [2000] Neugent, K.F. and P. Massey, PASP [in press, 2010]

320 *Joint Astrophysics and Planetary Science Studies From the Outer Solar System* Special Session *Room 611/612*

320.01 **Reaching the Outer Solar System Michael W. Werner¹** ¹*JPL/Caltech.* 2:00 PM - 2:15 PM *Room 611/612*

A variety of opportunities are available for sending a cruise phase instrument to the outer solar system, or for repurposing existing spacecraft for similar scientific purposes. I will summarize the programs within both the Planetary and the Astrophysics portfolios which might support these investigations, with

special emphasis on the schedule for near term opportunities. Based on work carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with NASA.

320.02

A New Era in Extragalactic Background Light Measurements: Galaxy Formation and Reionization Asantha R. Cooray¹

¹UC Irvine. 2:15 PM - 2:30 PM Room 611/612

What is the total radiative content of the Universe since the epoch of recombination? The extragalactic background light (EBL) spectrum captures the redshifted energy released from the first stellar objects, protogalaxies, and galaxies throughout cosmic history. Yet, we have not determined the brightness of the extragalactic sky from UV/optical to infrared wavelengths with sufficient accuracy to establish the radiative content of the Universe to better than an order of magnitude. Among many science topics, an accurate measurement of the EBL spectrum in optical and near-IR will address: What is the total energy released by stellar nucleosynthesis over cosmic history? Was significant energy released by non-stellar processes? Is there a diffuse component to the EBL? When did first stars appear and how luminous was the reionization epoch? Absolute optical to near-IR EBL spectrum down to the sufficient accuracy to study reionization can be established by wide field imaging at a distance of 5 AU or more or above the ecliptic plane where the zodiacal foreground is reduced by more than three orders of magnitude. This talk will summarize the key scientific goals of a potential outer Solar system EBL measurement through diffuse sky mapping.

320.03 Zodiacal Light from the Outer Solar System William T. Reach¹

¹USRA/SOFIA. 2:30 PM - 2:45 PM Room 611/612

The zodiacal light is sunlight scattered by interplanetary dust particles, which are produced by asteroids, comets, and Kuiper Belt Objects. The zodiacal light has been well observed in the inner Solar System, including Helios and Pioneer spaceprobes that have measured the radial density variation from 0.3 to 3 AU and recently Spitzer measuring the azimuthal structure at 1 AU. The outer Solar System remains a relatively new frontier. The outer System will contain debris from collisions among KBOs, long-period comets, micrometeorids from the inner Solar System, and interplanetary dust. Measuring the radial variation of dust density will determine the production rate from KBO collisions and determine whether KBO debris reach the inner Solar System, in which case it can be collected locally and studied in laboratories. I will present the state of knowledge of outer Solar System dust and the prospects for measuring the Outer Zodiacal Light.

320.04 **Treating Our Zodiacal Cloud As A Debris Disk Charles A. Beichman¹** ¹*JPL*. 2:45 PM - 3:00 PM *Room 611/612* Determining the properties of our own zodiacal cloud beyond the asteroid belt is extremely challenging from our vantage point at 1 AU. Material located within 1-3 AU of the Sun so dominates the emission that it is nearly impossible to determine the amount of more distant material. Yet this information is critical to understanding the relative contributions to the zodiacal cloud of asteroidal and cometary debris as well as of interstellar material. Utilization of instruments on spacecraft going to the outer solar system could add substantially to our knowledge of the evolution and spatial distribution of dust in the solar system. I will compare our knowledge of the dust in our own solar system to that gained from observations toward other stars.

320.05

Mass Measurements of Galactic Bulge Exoplanets via Observations from the Outer Solar System David P. Bennett $^{\rm 1}$

¹Univ. of Notre Dame. 3:00 PM - 3:15 PM Room 611/612

Gravitational microlensing is unique among exoplanet discovery methods for its sensitivity to low-mass planets located beyond the snow-line, where planet formation is thought to be the most efficient. For exoplanets orbiting stars in the Galactic disk, it is often possible to directly measure the mass of the planets via the microlensing parallax effect, due to the orbital motion of the Earth. But many of the exoplanets found by microlensing orbit stars in the Galactic bulge, and for these systems, the Earth's orbital motion does not allow a mass measurement. But, a few observations of the stellar lensing effect from a small telescope in the outer solar system will provide a mass measurements for these systems and allow us to determine the exoplanet mass function in the Galactic bulge.

320.06

Instrumentation for Astronomical Cruise-Phase Science

James J. Bock¹

¹Jet Propulsion Laboratory.

3:15 PM - 3:30 PM

Room 611/612

Observations from the outer solar system offer unique opportunities for astrophysical investigations. The greatly reduced foreground brightness from Zodical light, scattered sunlight and thermal emission by interplanetary dust, allows for measurements of the extragalactic background, and surveys of the composition and distribution of Kuiper belt dust. Furthermore parallax with earth-based observations provide unique information in microlensing events.

Compact, passively cooled instrumentation operating at optical to near-infrared wavelengths with small (2 - 15 cm) telescope apertures are optimal for these specialized science investigations. We have carried out a feasibility study for such instrumentation, which is small enough to be carried as a guest instrument package on a mission to the outer planets, and discuss its potential scientific capabilities.

321

Cluster Cosmology with Optical and SZ data Special Session *Room 615/617*

321.01 Optical Cluster Detection in the Post-SDSS Era Benjamin Koester¹ ¹University Of Chicago. 2:00 PM - 2:15 PM

Room 615/617

Near the conclusion of the first Sloan Digital Sky Survey, the development of optical cluster detection algorithms, quantification of their selection functions, and mass and redshift calibration hit full swing. Catalogs typically include thousands of massive (> $1x10^{14}$ M_{sun}) clusters reaching z~0.5, with selection functions that are routinely calibrated with realistic mock galaxy simulations, and cluster mass proxies that are cross-calibrated against X-ray, weak-lensing, dynamical, and SZ observations. All of this is folded into analyses that offer cosmological constraints competitive with catalogs created at other wavelengths.

In this talk, these developments are reviewed from the perspective of the MaxBCG cluster catalog. The lessons learned from optical cluster-finding efforts are then turned to the next generation of optical/NIR surveys soon to come online, using the Dark Energy Survey (DES) as an example. In DES, this past experience guides the coordination of vast resources that will culminate in well-understood cluster catalogs specifically tailored to cosmological applications reaching z^{1} .

321.02

Cosmology Constraints from Sunyaev-Zel'dovich Galaxy Clusters Detected with the Atacama Cosmology Telescope

Neelima Sehgal¹

¹Stanford University. 2:15 PM - 2:30 PM Room 615/617

For the first time microwave surveys such as the Atacama Cosmology Telescope (ACT) and the South Pole Telescope (SPT) are detecting galaxy clusters through the Sunyaev-Zel'dovich (SZ) effect. Counts of galaxy clusters as a function of mass and redshift provide a powerful probe of structure growth and cosmology. I will discuss constraints on the matter power spectrum amplitude, sigma₈, and dark energy equation of state, w, from SZ cluster counts detected with ACT.

321.03

Sunyaev Zel'dovich Array (SZA) Observations of an Optically Selected Cluster Sample Christopher Greer¹

¹University of Chicago. 2:30 PM - 2:45 PM Room 615/617

We present the early results of a study of 24 galaxy clusters selected as a volume-limited sample from the Sloan Digital Sky Survey (SDSS). The sample contains the 24 richest clusters in the SDSS maxBCG catalog between redshift 0.15 and 0.3, and has complimentary SZA and Chandra observations for each cluster. We measure the scaling and covariance of these different data sets, specifically focusing on the SZ and optical data. Several previous studies have shown that combining information from different frequencies reduces systematics inherent in observations in the individual frequencies. By doing so, we hope to lay the groundwork for precision cosmology with large, optically-selected cluster samples combined with SZ data, such as from the Dark Energy Survey and the South Pole Telescope.

321.04

Physical Properties and Purity of an SZE Cluster Sample Using the Atacama Cosmology Telescope Felipe Menanteau¹, ACT Collaboration

¹*Rutgers University.* 2:45 PM - 3:00 PM

Room 615/617

We present optical and X-ray properties for the first confirmed galaxy cluster sample selected by the Sunvaev-Zel'dovich Effect from 148 GHz maps over 455 square degrees of sky made with the Atacama Cosmology Telescope. These maps, coupled with multi-band imaging on 4-meter-class optical telescopes, have yielded a sample of 23 galaxy clusters with redshifts between 0.118 and 1.066. Of these 23 clusters, 10 are newly discovered. The selection of this sample is approximately mass limited and essentially independent of redshift. We provide optical positions, images, redshifts and X-ray fluxes and luminosities for the full sample, and X-ray temperatures of an important subset. The mass limit of the full sample is around 8.0e14 Mo, with a number distribution that peaks around a redshift of 0.4. For the 10 highest significance SZE-selected cluster candidates, all of which are optically confirmed, the mass threshold is 1e15 Mo and the redshift range is 0.167 to 1.066. Archival observations from Chandra, XMM, and Rosat provide X-ray luminosities and temperatures that are broadly consistent with this mass threshold. Our optical follow-up procedure also allowed us to assess the purity of the ACT cluster sample. Eighty (one hundred) percent of the 148 GHz candidates with signal-to-noise ratios greater than 5.1 (5.7) are confirmed as massive clusters. The reported sample represents one of the largest SZEselected sample of massive clusters over all redshifts within a cosmologically-significant survey volume, which will enable cosmological studies as well as future studies on the evolution, morphology, and stellar populations in the most massive clusters in the Universe.

Financial support was provided by the NSF under the PIRE program (OISE-0530095).

321.05

Towards Precision Cosmology With Optically Selected Cluster Catalogs Eduardo Rozo $^{\rm 1}$

¹University of Chicago.

3:00 PM - 3:15 PM

Room 615/617

Precision cosmology with galaxy clusters requires that: a- the cluster selection function be well undestood. b- the relation between cluster mass and the cluster observable used to trace mass be completely characterized. Indeed, all current cluster cosmological constraints are systematics limited by one or both of these requirements. Given the unparalled statistical precision that near future cluster catalogs can achieve, succesfully resolving these difficulties is now more urgent than ever. In this talk, we review ongoing work aimed at addressing these problems within the context of optical cluster cosmology, focusing particularly on where we are now and what remains to be done.

321.06

The South Pole Telescope: Cluster Catalog and Cosmological Results Bradford Benson 1

¹University of Chicago. 3:15 PM - 3:30 PM *Room 615/617*

The 10-meter South Pole Telescope (SPT) is a millimeter wavelength telescope designed to conduct sensitive measurements of the cosmic microwave background (CMB) at arc-minute resolution. Currently the SPT is conducting a 2500 square degree survey to find clusters of galaxies from their distortion of the CMB, known as the Sunyaev-Zel'dovich (SZ) effect. The surface brightness of the SZ effect is redshift independent which allows a SZ survey to provide a nearly mass limited cluster sample out to the earliest epochs of cluster formation. Currently, the SPT has surveyed over 1200 square degrees and has identified hundreds of cluster candidates. Of these, over 200 have been optically confirmed, with the

majority being newly discovered clusters at z > 0.5. We will summarize the first results from the SPT cluster survey, including cosmological constraints from their measurement of the growth of structure.

322

Circumstellar Disks I and Sedna Oral Session *Room 618/620*

322.01

Accretion Variability in Turbulent Disks

Jacob B. Simon¹, J. F. Hawley², K. Beckwith¹ ¹*JILA/University of Colorado,* ²*University of Virginia.* 2:00 PM - 2:10 PM *Room 618/620*

The most promising candidate for angular momentum transport in accretion disks is magnetohydrodynamic turbulence driven by the magnetorotational instability (MRI). Most numerical simulations of MRI-driven turbulence are performed in the local, unstratified approximation: a small, corotating patch of accretion disk is evolved and the vertical component of gravity is ignored. Recently, these simulations have shown that turbulence levels increase with the ratio of the gas shear viscosity to Ohmic resistivity, i.e., the magnetic Prandtl number. Here, I present a series of local simulations that include vertical gravity in order to further investigate the Prandtl number effect in a more astrophysically relevant context. These calculations show that for moderate resistivities, the MRI saturation level exhibits a very strong temporal variability; the turbulence episodically transitions between "high" and "low" states on timescales of ~100 local orbits. This behavior is directly linked to a dynamo mechanism present in vertically stratified local simulations and may have relevance for accretion variability in partially ionized disks, such as dwarf novae and protoplanetary disks.

322.02D

Mixing of Dust in Protoplanetary Disks and the Solar Nebula

Anna L. Hughes¹

¹University of Colorado-JILA. 2:10 PM - 2:30 PM

Room 618/620

Understanding the evolution of gas and dust within protoplanetary disks is important for planet formation, for modeling astronomical observations of disks, and for interpreting mineralogical constraints on the Solar Nebula. The gas and solid components undergo distinct physical processes, but their evolution is coupled by aerodynamic forces whose strength varies with particle size. I will present models of the evolution of the radial distribution of dust grains that incorporate the effects of disk evolution (outward expansion and inward accretion), radial and azimuthal drag of the gas flow on the particle orbits, and the turbulent mixing of the particle ensemble radially within the disk. I will show results for the extent of radial mixing of hot, inner-disk particles, outward to large AU, and for the global evolution of the gas-to-dust ratio within the disk. I will discuss the relevance of the results for interpreting data from the Stardust mission, and for theoretical models of planetesimal formation.

322.03D

Transitional And Pre-transitional Disks: Gap Opening By Multiple Planets?

Zhaohuan Zhu¹, L. Hartmann¹, R. Nelson², N. Calvet¹, C. Espaillat³

¹University of Michigan, ²Astronomy Unit, Queen Mary, University of London, United Kingdom, ³Center for Astrophysics.

2:30 PM - 2:50 PM

Room 618/620

We use two-dimensional hydrodynamic simulations of viscous disks to examine whether dynamicallyinteracting multiple giant planets can explain the large gaps inferred for the transitional and pretransitional disks around T Tauri stars. In the absence of inner disk dust depletion, we find that it requires three to four giant planets to open up large enough gaps to be consistent with inferences from spectral energy distributions, because the gap width is limited by the tendency of the planets to be driven together into 2:1 resonances. With very strong tidal torques and/or rapid planetary accretion, fewer planets can also generate a large cavity interior to the locally formed gap(s) by preventing outer disk material from moving in. In these cases, however, the reduction of surface density produces a corresponding reduction in the inner disk accretion rate onto the star; this makes it difficult to explain the observed accretion rates of the pre/transitional disks. We find that even with planet(s) in disks, additional substantial dust depletion is required to explain observed disk gaps/holes. Substantial dust settling and growth, with consequent significant reductions in optical depths, is inferred for typical T Tauri disks in any case, and an earlier history of dust growth is consistent with the hypothesis that pre/transitional disks are explained by the presence of giant planets. We suggest that in the pre/transitional disks, giant planet formation modifies this general process by forming a gap with abrupt changes in surface density, producing a thick outer disk ``wall" which can be strongly irradiated by the central star, while scattering and clearing inner planetesimals that otherwise might collide and produce secondary small dust.

322.04

Protoplanetary Disk Modes and Type I Migration David Tsang^1

¹California Institute of Technlogy.

2:50 PM - 3:00 PM

Room 618/620

In Type I planetary migration, the planet excites a wake in the circumstellar disk, which in turn tends to drive the planet inwards towards the central star at a timescale much faster than the timescale required for planet formation. Here we consider the effect of a trapped azimuthal mode of the wake near the edge or gap of a protoplanetary disk. We show that under certain conditions wave trapping can stall the process of Type I migration.

322.05

Alexander's and Phoebe's stars: Two New Exotic Phoenix Giants

Carl Melis¹, B. Zuckerman², I. Song³, J. H. Rhee³, M. S. Bessell⁴, S. J. Murphy⁴ ¹UC San Diego, ²UC Los Angeles, ³University of Georgia, ⁴The Australian National University, Australia. 3:00 PM - 3:10 PM

Room 618/620

Phoenix Giants are first-ascent giant stars orbited by substantial dusty and gaseous disks that are sometimes accreting onto the central star. We present the characterization of two dusty first-ascent giant stars identified through cross-correlating the Tycho-2 and IRAS catalogs. CD-30 11814 (hereafter Alexander's star) is a high-velocity Pop II star that exhibits rapid accretion and outflowing gas. Multiple

epochs of spectroscopic observations show that the double-peaked Ca II infrared triplet emission from this source has variable morphology and strength. TYC 596 145 1 (hereafter Phoebe's star) is a lithium-rich K2.5 III star orbited by a substantial icy disk as indicated by water-ice features detected in Spitzer IRS and IRTF/SpeX infrared spectroscopy. Each source can yield interesting insights into binary star evolution and planetary systems.

Funding for this research came from NASA grants and an LLNL-Minigrant to UCLA and from the Spitzer Visiting Graduate Student Program.

322.06

Sedna and the Evolving Solar Neighborhood

Nathan A. Kaib¹, R. Roskar², T. Quinn³

¹Queen's University, Canada, ²University of Zurich, Switzerland, ³University of Washington. 3:10 PM - 3:20 PM

Room 618/620

The trans-Neptunian object (TNO) Sedna is puzzling because its orbit displays evidence of significant gravitational perturbations from the local galactic environment even though its proximity to the Sun implies the odds of a "Sedna-perturbing" field star passage are improbably small. Consequently, many alternative formation scenarios have been proposed. However, new galactic evolution models suggest the Sun's radial position in the Milky Way (and hence its local galactic environment) has varied dramatically during its history. In particular, they find that the Sun may have formed closer to the Galactic center where local stellar densities are higher. Using numerical simulations that account for the Sun's migration within the Galaxy, we demonstrate that it is in fact quite plausible for normal passing field stars to generate Sedna-like orbits. Depending on the Sun's orbital history, the probability of Sedna being generated by a simple field star passage varies between ~2 and 50%. In contrast to other models, we predict a small population of Sedna-like bodies whose orbits could have been sculpted Gyrs after solar system formation. Thus, Sedna's orbit may not require a special dynamical mechanism and may fit within the framework of an Oort Cloud sculpted by the conventional perturbations of passing field stars and the Milky Way tide.

323

The Milky Way, The Galactic Center Oral Session *Room 613/614*

323.01
Results From The Quad Galactic Plane Survey
Thomas Culverhouse¹
¹CARMA.
2:00 PM - 2:10 PM
Room 613/614
Large code, bick recolution millimeter wave of

Large-scale, high-resolution millimeter-wave observations of the galactic plane provide important measurements of the statistics of clumps hosting cold, dense star-forming regions, and the properties of unpolarized and polarized thermal dust, which present a challenging foreground problem for microwave background experiments probing the signature of inflation, the 'B-mode' polarization . The QUaD galactic plane survey has mapped 800 square degrees of the low-latitude Milky Way in the Southern Hemisphere. Stokes I, Q and U parameters are measured at 100 and 150 GHz, with angular resolution 5 and 3.5 arcmin respectively. I will present measuments of the spectral properties and polarization fractions from diffuse emission, and a catalog of discrete sources extracted from the survey maps will be

also described, including rare polarized compact sources. This survey was funded by the National Science Foundation (US) and the Particle Physics and Astronomy Research Council (UK).

323.02D Halo Substructure and Milky Way Formation Kevin Schlaufman¹

¹UC Santa Cruz. 2:10 PM - 2:30 PM Room 613/614

The accretion history of the Milky Way is partially encoded in its halo substructure. I describe the results of a systematic statistical search for elements of cold halo substructure (ECHOS) in the radial velocity distribution of stars in the inner halo of the Milky Way observed during the Sloan Extension for Galactic Understanding and Exploration (SEGUE) survey. Radial velocity substructure is systematically older than surface brightness substructure (e.g., tidal streams), and therefore provides a direct measure of the accretion history of the Milky Way in a region and time interval that has yet to be fully explored. In addition, I measure average chemical abundance properties in both ECHOS and in the kinematically smooth inner halo stellar population. I find that ECHOS are unlikely to be disrupted globular clusters or ultrafaint dwarf spheroidal (dSph) galaxies, and there is evidence to suggest they are the debris of $M_{tot} \sim 10^9$ solar mass dSph galaxy or galaxies. Spatial correlations in line of sight averaged abundance measurements in the smooth halo population indicate that the contribution of disrupted dSph galaxies to the smooth halo population increases with Galactocentric radius.

This material is based upon work supported under a National Science Foundation Graduate Research Fellowship.

323.03

Thick Disk Formation by Radial Migration in Barred Galaxies Ivan Minchev $^{\rm 1}$

¹Astrophysical Institute Potsdam (AIP), Germany. 2:30 PM - 2:40 PM Room 613/614

We investigate the dynamical effect of central bars and spirals in galactic disks by means of Tree-SPH and pure N-body simulations. We find that the strong radial mixing induced by the resonance overlap of the bar and spirals (Minchev & amp; Famaey 2010) causes the formation of a thick disk component, provided the bar and spiral structure are sufficiently strong for a couple of Gyr. Due to adiabatic cooling, the migrated stars (coming mostly from the bulge) decrease their velocity dispersion in the vertical direction, thus preventing disk flaring: the scale-hight is roughly constant with radius at any given time. We show that the vertical density profile and the velocity and eccentricity stellar distributions in a simulated solar neighborhood are consistent with recent analysis of the GCS and RAVE data. Our results not only confirm the suggestion by Schonrich & amp; Binney (2009) that the Milky Way thick disk could have originated by secular evolution, but also imply that radial migration from resonance overlap may be the dominant thick disk formation mechanism in barred spirals (>2/3 of disk galaxies). We propose some observational tests which can help discriminate between different thick disk formation scenarios.

323.04D

The Dual Origin of Galactic Stellar Halos Adi Zolotov¹ ¹*New York University.* 2:40 PM - 3:00 PM

Room 613/614

Accreted stellar halos are a natural consequence of galaxy formation in a Lambda-CDM Universe, and contain unique fossil records of hierarchical galaxy formation. The properties of local Milky Way halo stars, however, suggest that the Galaxy's halo is composed of at least two distinct stellar populations, each exhibiting different spatial distributions, orbits, and metallicities. This observed dichotomy is the result of the assembly history of the halo, which likely formed through a process more complex than pure hierarchical accretions. In this talk I will describe the formation of stellar halos surrounding Milky Way-massed disk galaxies simulated using high-resolution cosmological Smooth Particle Hydrodynamics + N-Body simulations. We find that two competing physical processes - accretion of dwarf galaxies and in situ star formation - contribute to the formation of every stellar halo. While the outer regions (r > 20 kpc) of the halos were assembled solely through the accretion and disruption of satellites, in situ star formation supplements accretion in the formation of inner halos. The relative contribution of each stellar population to a halo is shown to be a function of a galaxy's merging history. Galaxies with recent mergers, like M31, will host relatively few in situ stars, while galaxies with more quiescent recent histories, like the Milky Way, will likely have a larger population of such stars. We show how the chemical abundance trends ([Fe/H] vs. [alpha/Fe]) of accreted and in situ stars diverge at the high [Fe/H] end of the metallicity distribution function, and discuss how such trends can be used to study and identify the observable imprints of the Milky Way's formation history.

323.05

ISO-LWS Observations Of Gas And Dust In The Galactic Centre

Mireya Etxaluze Azkonaga¹, H. Smith¹, E. Gonzalez-Alfonso², G. J. White³

¹Harvard-Smitsonian Center for Astrophysics, ²Universidad de Alcala, Spain, ³The Open University, United Kingdom.

3:00 PM - 3:10 PM

Room 613/614

The ISO-LWS observed Sagittarius A^* over the wavelength range of 46-197 μ m. These previously unpublished spectra contain about 22 spectral lines in emission of atomic and ionic species (OI, OIII, CII, NII and NIII), as well as emission and absorption lines from molecular species (OH, CH, CO and o-H2O). ISO mapped the region in a 40 position, half-beam sampled grid, and used both the grating and Fabry-Perot modules. We have prepared spectral maps of most of the lines, but here discuss primarily the radiative transfer modelling of radiation within the central beam on Sgr A^{*}. We used ISO-LWS spectra to constrain the physical conditions in Sgr A^{*} by comparing the observed spectra with the emission and the absorption line intensities predicted via radiative transfer simulations. Preliminary results show that the spectral energy distribution of Sgr A^{*} within the 80" ISO beam that includes the CND is due to thermal dust emission that can be fitted by the sum of an 85 K modified blackbody arising from a central cavity of r=1.2 pc in radius with a low column density of $N(H_2)=4.0 \times 10^{21}$ cm², and a 40.5 K modified blackbody curve and a higher column density, $N(H_2) = 3.0 \times 10^{22}$ cm². This simple model is able to reproduce most of the ionic lines, which are excited in the CND; the central cavity provides only a small contribution to the intensity of the spectral lines. The molecular lines, and in particular the OH absorption features, require substantive additional contributions from foreground absorption that is consistent with a visual extinction $A_V \sim 30$, the same value that is derived from other studies.

323.06

Highlights of the 2008 Observing Campaign of Sgr A*

Farhad Yusef-Zadeh¹, A. Brunthaler², H. Bushouse³, K. Dodds-Eden², D. Dowell⁴, P. Edwards⁵, S. Gillessen², R. Genzel², C. Heinke⁶, C. Martin⁷, D. Marrone⁸, A. Miyazaki⁹, D. Munoz¹⁰, D. Plambeck¹¹, M. Reid¹², D. Roberts¹³, J. Stevens⁵, T. Tzioumis⁵, M. Wardle¹⁴, A. Weiss², H. Wiesemeyer¹⁵

¹Northwestern Univ., ²MPI, Germany, ³STScI, ⁴Caltech, ⁵CSIRO, Australia, ⁶University of Alberta, Canada, ⁷Oberlin College, ⁸Univ. Chicago, ⁹NAO, Japan, ¹⁰Harvard U., ¹¹UC Berkeley, ¹²CfA, ¹³Adler Planetarium, ¹⁴Macquarie U., Australia, ¹⁵IRAM, Spain.

3:10 PM - 3:20 PM

Room 613/614

We have carried out multi-wavelength observations of Sgr A* in May and July of 2008 using the Chandra X-ray Observatory, APEX, ATCA, CARMA, CSO, IRAM, NMA, SMA, SMT, VLA, VLBA and VLT. Previous measurements have shown time delayed emission between near-IR and radio/submm. Here, we present two new aspects of the variability of Sgr A* across the electromagnetic spectrum. One is evidence for dimming of submm and radio flux during the peak of near-IR flare emission. This is consistent with recent finding that the variability of Sgr A* in radio and submm wavelengths is anti-correlated with near-IR flare emission. This newly recognized behavior is consistent with adiabatically cooling plasma blobs that are expanding but also partially eclipsing the background quiescent emission from Sgr A*. The second

result is that cross correlation of X-rays and near-IR light curves suggests that X-ray flare emission lags behind near-IR flare emission by several minutes. This implies that X-ray

emission is due to inverse Compton scattering of near-IR flare emission by submm emitting electrons.

323.07

Methanol Maser Emission toward Sources with Excess 4.5 um Emission ('Green Fuzzies') in the Galactic Center

Edward Thomas Chambers¹, F. Zadeh¹, D. Roberts¹

¹Northwestern University.

3:20 PM - 3:30 PM

Room 613/614

Understanding the processes occurring in the nuclear disk of our own Galaxy (2 x 1.5 degrees of the Galactic center) is interesting not only for insight into our own Milky Way Galaxy, but also because it is the closest galactic nucleus. The nature of on-going star formation in the nuclear region, however, is not well-understood. In order to better understand this process, we compare how sources with excess 4.5 um emission correlate with 6.7 GHz methanol maser emission in the Galactic center, as well as in the Galactic disk. These excess 4.5 um emission sources, called 'green fuzzies' for how they appear in 3-color IRAC images (with 8 um in red, 4.5 um in green, and 3.6 um in blue), are usually found within infrared dark clouds (IRDCs), and are likely sites of star formation. Because radiatively excited Class II 6.7 GHz methanol masers are also signposts of star formation toward a subset of Galactic center. In addition, we search for another indicator of star formation toward a subset of Galactic center green fuzzies: collisionally excited, Class I 44 GHz methanol maser emission. Here, we present the results of our study of the correlation of green fuzzies with 6.7 GHz and 44 GHz methanol masers.

324

Supernovae II - Type Ia Oral Session *Room 609*

324.01
Hierarchical Models for Type Ia Supernova Light Curves in the Optical and Near Infrared Kaisey Mandel¹, G. Narayan¹, R. P. Kirshner¹
¹Harvard University.
2:00 PM - 2:10 PM

Room 609

I have constructed a comprehensive statistical model for Type Ia supernova optical and near infrared light curves. Since the near infrared light curves are excellent standard candles and are less sensitive to dust extinction and reddening, the combination of near infrared and optical data better constrains the host galaxy extinction and improves the precision of distance predictions to SN Ia. A hierarchical probabilistic model coherently accounts for multiple random and uncertain effects, including photometric error, intrinsic supernova light curve variations and correlations across phase and wavelength, dust extinction and reddening, peculiar velocity dispersion and distances. An improved BayeSN MCMC code is implemented for computing probabilistic inferences for individual supernovae and the SN Ia and host galaxy dust populations. I use this hierarchical model to analyze nearby Type Ia supernovae with optical and near infared data from the PAIRITEL, CfA3, and CSP samples and the literature. Using cross-validation to test the robustness of the model predictions, I find that the rms Hubble diagram scatter of predicted distance moduli is 0.11 mag for SN with optical and near infrared data versus 0.15 mag for SN with only optical data. Accounting for the dispersion expected from random peculiar velocities, the rms intrinsic prediction error is 0.08-0.10 mag for SN with both optical and near infrared light curves. I discuss results for the inferred intrinsic correlation structures of the optical-NIR SN Ia light curves and the host galaxy dust distribution captured by the hierarchical model. The continued observation and analysis of Type Ia SN in the optical and near infrared is important for improving their utility as precise and accurate cosmological distance indicators.

324.02

Some Results From a Study on the Effect of Host Galaxy Dust Extinction on the Colors of Type Ia Supernovae

Aleksandar Cikota¹, S. Deustua², K. Gordon²

¹University of Zurich, Switzerland, ²Space Telescope Science Institute.

2:10 PM - 2:20 PM

Room 609

We present some results from a study to examine the effect of host galaxy dust extinction on the observed properties of Type Ia supernovae (SNe Ia). The Spitzer Infrared Nearby Galaxies Survey (SINGS) is a comprehensive infrared survey of 75 nearby galaxies (Kennicutt et al. 2003) that have good estimates of their dust masses (Draine et al. 2007). Twelve SNe Ia have been observed in a subset of the sample, and therefore provide a good laboratory to test, and bound, the uncertainties in observed SNe Ia colors. Using the SINGS data, Draine's standard dust model, and SNe Ia template spectra (Hsiao et al. 2007), we compared the historical SNe Ia to the computed model spectra. We will discuss our results for these SNe.

Aleksandar Cikota was a participant in the the STScl Summer Student Program and supported by the STScl Director's Discretionary Research Fund.

324.03

Type Ia Supernovae and the Single Common Envelope Scenario

Eric Blais¹, L. Nelson¹ ¹*Bishop's University, Canada.* 2:20 PM - 2:30 PM

Room 609

Double degenerate white dwarfs systems (DDWDs) are still very probable progenitors for Type Ia supernovae (SNe Ia). We have investigated scenarios for the formation of DDWDs. Using Monte Carlo simulations, a population of SNe Ia progenitors was synthesized. According to the channel that we considered, the evolution of massive "twins" was followed until they reached the giant phase at which

point some of them came into contact and formed a single common envelope. In many cases, a double degenerate system was formed as a result of this process. We found that a significant proportion of the "prompt" population of SNe Ia can be explained in this way. We believe that a significant fraction of the remaining SNe Ia progenitor population can be obtained by considering stable Roche lobe overflow while one star is still on the main sequence, followed by a phase of common envelope evolution (i.e., the single-degenerate channel).

324.04

The Rise-Time Distribution of Nearby Type Ia Supernovae

Mohan Ganeshalingam¹, W. Li¹, A. Filippenko¹

¹UC Berkeley. 2:30 PM - 2:40 PM

Room 609

We present an analysis of the rise-time distribution of nearby (z< 0.05) Type Ia supernovae (SNe Ia). Drawing mostly from the recently published Lick Observatory Supernova Search (LOSS) SN Ia sample along with other published nearby SNe Ia with data starting at least ten days before maximum brightness, we use a two-stretch template-fitting method to measure the rise and decline of light curves compared to a fiducial template. We find a correlation between the decline and rise of the light curve in the sense that SNe with slow decline rates have longer rise-times. A comparison of the rise-time distribution of spectroscopically normal SNe Ia to SNe Ia with high-velocity spectral features indicates possible differences in their parent distributions. We gratefully acknowledge the financial support of NSF grant AST-09088886 and the TABASGO Foundation.

324.05

Berkeley SuperNova Ia Program (BSNIP): Initial Spectral Analysis

Jeffrey Silverman¹, J. Kong¹, M. Ganeshalingam¹, W. Li¹, A. V. Filippenko¹

¹University of California - Berkeley.

2:40 PM - 2:50 PM

Room 609

The Berkeley SuperNova Ia Program (BSNIP) has been observing nearby (z < 0.1) Type Ia supernovae (SNe Ia) both photometrically and spectroscopically for over two decades. Using telescopes at both Lick and Keck Observatories, we have amassed an extensive collection of well-sampled optical light curves with complementary spectra covering, on average, 3400-10,000 Å. In total, we have obtained nearly 600 spectra of over 200 SNe Ia with densely sampled multi-color light curves.

The initial analysis of this dataset consists of accurately and robustly measuring the strength and position of various spectral features near maximum brightness. We determine the endpoints, pseudo-continuum, expansion velocity, equivalent width, and depth of each major feature observed in our wavelength range. For objects with multiple spectra near maximum brightness we investigate how these values change with time. From these measurements we also calculate velocity gradients and various flux ratios within a given spectrum which will allow us to explore correlations between spectral and photometric observables. Some possible correlations have been studied previously, but our dataset is unique in how self-consistent the data reduction and spectral feature measurements have been, and it is a factor of a few larger than most earlier studies.

We will briefly summarize the contents of the full dataset as an introduction to our initial analysis. Some of our measurements of SN Ia spectral features, along with a few initial results from those measurements, will be presented. Finally, we will comment on our current progress and planned future work.

We gratefully acknowledge the financial support of NSF grant AST-0908886, the TABASGO Foundation, and the Marc J. Staley Graduate Fellowship in Astronomy.

324.06D

On the Role of Turbulence in Type Ia Supernovae

Aaron P. Jackson¹, A. C. Calder¹, D. M. Townsley², D. A. Chamulak³, E. F. Brown⁴, F. X. Timmes⁵ ¹Stony Brook University, ²The University of Alabama, ³Argonne National Laboratory, ⁴Michigan State University, ⁵Arizona State University.

2:50 PM - 3:10 PM

Room 609

Type Ia supernovae (SNeIa) are bright astrophysical explosions that form a remarkably homogeneous class of objects used to study the expansion history of the Universe and the nature of Dark Energy. However, details of the explosion mechanism and the influence of properties of the host stellar population remain incompletely understood. The most widely accepted scenario for a SNIa to occur is the explosion of a near-Chandrasekhar mass white dwarf. Under this scenario, the thermonuclear explosion begins as a deflagration (subsonic burning) near the center that transitions to a detonation (supersonic burning) some time later. Turbulence, particularly its interaction with the flame, plays a key role throughout the evolution of the explosion process. Pre-existing turbulence from a vigorous convection field encompassing roughly 70% of the star will influence the evolution of the early flame, while turbulence generated by fluid instabilities is thought to interact with the flame such that a deflagration-to-detonation transition (DDT) occurs. As I will show, the DDT density strongly influences the yield of radioactive ⁵⁶Ni that powers the light curve. While the conditions under which a DDT occurs remains an area of active research, it is thought to be influenced by the metallicity of the progenitor. I will offer an explanation of observed trends in the peak brightness of SNeIa with host galaxy metallicity from results of a suite of two-dimensional simulations in which the DDT density was varied. I will also present improvements to our flame model for the enhancement of burning by turbulence and discuss its application in three-dimensional simulations of the impact of pre-existing turbulence on the early flame evolution. This work was supported by NASA under grant No. NNX09AD19G.

325

Evolution of Galaxies VII Oral Session *Room 608*

325.01D

The Evolution Of The Ly-alpha Photon Escape Fraction In Galaxies: Constraints From The UV-slope And Luminosity Function Of Spectroscopically Detected LAEs At 2<z<4.

Guillermo A. Blanc¹, J. Adams¹, K. Gebhardt¹, G. J. Hill¹, N. Drory²

¹University of Texas at Austin, ²Max-Planck-Institut für extraterrestrische Physik, Germany.

2:00 PM - 2:20 PM

Room 608

I will present results based on a sample of 97 spectroscopically detected LAEs at 2<z<4 from the HETDEX Pilot Survey for Emission Line Galaxies. We measured the UV-slope, dust-content, SFR, and Ly-alpha escape fraction in these objects, as well as their evolution with redshift. I will discuss the role of dust on the escape of Ly-alpha photons from these galaxies. In particular, our results show that the relation between the Ly-alpha escape fraction and E(B-V) for the bulk of the LAE population indicates that strong enhancements of the escape fraction due to the presence of a clumpy multi-phase ISM, is not a common process in galaxies. We also measure the Ly-alpha luminosity function at 2<z<4, and combine it with previous measurements in the 0<z<7 range to study the evolution of the Ly-alpha luminosity density.

Comparing the observed evolution to that predicted from the SFR history of the universe we measure the evolution of the average Ly-alpha escape fraction for the overall galaxy population. We find it to sharply fall from roughly 100% at z^{-6} to 5% at z^{-2} , remaining at this low value all the way to z=0. We interpret this behavior as the consequence of an increase in the dust-content of galaxies from z^{-6} to 2. This increase has been previously claimed from the observed evolution of the UV slope of continuum selected high redshift galaxies, and our results provide independent evidence for it. On the other hand the dust properties of LAEs

do not seem to evolve significantly from z~4 to 2, indicating that Ly-alpha selection picks up similar objects at different redshifts.

325.02D

The Atacama Cosmology Telescope Project: Extragalactic Millimeter Wave Point Sources at 148 and 218 GHz

Danica Marsden¹

¹University of Pennsylvania.

2:20 PM - 2:40 PM

Room 608

> We present the set of extragalactic sources detected in a 455 square-degree map of the southern sky made with data at frequencies of 148 GHz and 218 GHz from the Atacama Cosmology Telescope (ACT). I will discuss the ACT survey and properties (e.g., spectral indices and differential counts) of these source populations. I will also discuss a follow-up study with the Australia Telescope Compact Array to better characterize these populations in a frequency/flux regime that is only now being explored thoroughly. Effects of these populations in the context of the high-ell CMB secondary anisotropy power spectrum and on SZE cluster surveys are explored.

325.03

Exploring z=0.2 Compact UV-luminous Galaxies With The Magellan/Imacs IFU

Karin Menendez-Delmestre¹, L. Bai¹, T. S. Gonçalves², K. Ludlum³, D. R. Law⁴, R. Overzier⁵ ¹Carnegie, ²California Institute of Technology, ³Pomona College, ⁴UCLA, ⁵MPA, Germany. 2:40 PM - 2:50 PM

Room 608

Recent studies using Keck and VLT integral field units (IFU) have unveiled the spatially-resolved detailed kinematics of star-forming monsters at z~2-3, close to the peak in star-formation rate density. Optically-selected galaxies have been the principal targets of these studies. Although disagreement concerning whether systemic rotation or turbulent motions dominate the internal dynamics of these objects, authors agree in their findings of high velocity dispersions, up to ten times the velocity dispersions in the local Universe (~10 km/s). It remains an open question whether these findings are representative of "normal" galaxies at high redshift. Current instrument sensitivities limit our exploration of the high-redshift universe to the most extreme, massive and luminous cases. Although stacking analysis allow us to probe for the less-luminous galaxy populations, a myriad of open questions remain on the astrophysical details of the galaxy "garden-variety" at these high redshifts.

More recently, a sample of super-compact UV-luminous galaxies unveiled by the Galaxy Evolution Explorer (GALEX) has been shown to be an excellent local analog at $z^0.2$ for the high-redshift Lyman-Break Galaxy population. We have undertaken the study of a sample of compact UV-luminous galaxies at $z^0.2$, which are complementary to these Lyman-break local analogs in the interest of exploring the similarities (or perhaps differences) of the less-massive, yet strongly starbursting systems that highredshift studies are unable to probe. We have targeted a sample of ~10 compact UVLGs with Magellan/IMACS using the Integral Field Unit mode, which gives us access to the full rest-frame optical line emission of these $z^{0.2}$ objects. Through a simultaneous spatial and spectral insight we seek to obtain unparalleled insight to the distribution of dust (as given by the distribution of the observed Balmer decrement), metallicity and internal kinematics of these objects.

325.04

The Prevalence and Properties of Outflowing Winds at z = 1

Katherine Kornei¹, A. E. Shapley¹, C. L. Martin², A. L. Coil³

¹*UCLA,* ²*UCSB,* ³*UCSD.* 2:50 PM - 3:00 PM

Room 608

Outflowing winds have been observed in galaxies at a variety of redshifts and are thought to play an important role in both the quenching of star formation and the enrichment of the intergalactic medium. We present the results of a study at z = 1 tracing the prevalence and properties of outflows in a sample of DEEP2 objects with rest-frame UV spectroscopy and HST optical imaging. We investigate if a critical star formation rate surface density is required to drive outflows, using a new technique for estimating galaxy area based on a physically motivated luminosity threshold. Previous work has suggested that the star formation rate surface density may be most strongly correlated with outflows (as opposed to the star formation rate); our method of estimating the area over which star formation is occuring represents an improvement over the simple adoption of a Petrosian or half-light radius. We discuss fine structure FeII emission in light of galaxy properties and investigate the likely origin of these features (which are not commonly observed in local starbursts). By conducting analyses on a per-object basis at z = 1, we are able to examine the relationship between outflow properties and individual galaxy morphology, stellar populations, and star formation surface density, at the epoch when the global star formation rate is beginning its decline to the present day.

325.05

Shock acceleration of Relativistic Particles in Galaxy-Galaxy Collisions

Heinz Voelk¹, U. Lisenfeld²

¹Max-Planck-Institut fuer Kernphysik, Germany, ²Departamento de Fisica y del Cosmos, Universidad de Granada, Spain.

3:00 PM - 3:10 PM

Room 608

All galaxies without a radio-loud AGN follow a tight correlation between their global FIR and radio synchrotron luminosities, which is believed to be ultimately the result of the formation of massive stars. A much discussed but controversial physical explanation is the ``calorimeter theory'' which stipulates that galaxies are, at least approximately, calorimeters for their own UV radiation as well as for the relativistic electrons produced at the end of their stars life cycle. Interestingly, two colliding pairs of galaxies, UGC12914/5 and UGC 813/6 deviate from this correlation and show an excess of radio emission which in both cases originates to a large extent in a gas bridge connecting the two galactic disks. These objects have been interpreted as showing that the energetic electrons escape from their parent galaxies rather than loose their energy in the galactic magnetic fields. We argue here in an analytic model that the gas-dynamic interaction of the two Interstellar Media necessarily produces two strong shock waves which diffusively accelerate a new population of energetic particles. It can readily explain the excess radio emission from the gas bridge and thereby the deviation from the FIR-radio correlation for the combined system. The accompanying high-energy gamma-ray emission is too low for detection with present instruments, but might be detectable with a future gamma-ray instrument like CTA. Also the synchrotron spectral index at the present epoch agrees with the observations. The acceleration of relativistic electrons in shocks caused by an ISM collision, in the same way as described

here, is likely to take place in other systems as well, as in galaxy clusters and groups or high-redshift systems.

325.06

The Evolution of Emission Lines in Massive Early Type Red Galaxies Nicholas Konidaris¹

¹Caltech. 3:10 PM - 3:20 PM

Room 608

Massive early type red galaxies (MERGs) are typically thought to be "red and dead": in particular devoid of gas ionized by star formation. Contrary to this view, MERGs do show gas emission. In this talk I will present the evolution in the luminosity density of the forbidden emission line [O II], a common star formation rate tracer. Based on this evolution rate I will comment on possible ionizing sources for the gas. Without further data, however, it is not clear if the ionization source is star formation, AGN activity, or some other mechanism.

325.07

The Discrete X-ray Source Population of M82

Roy E. Kilgard¹, T. P. Roberts², F. E. Jackson², Great NASA Observatories M82 Extended Survey Team ¹Wesleyan University, ²Durham University, United Kingdom.

3:20 PM - 3:30 PM

Room 608

M82 is the prototypical starburst galaxy in the nearby universe. As such, it is an excellent laboratory for studying high-mass X-ray binaries. We present an initial analysis of the discrete source population of M82, with an emphasis on the ultraluminous X-ray sources, using new and archival observations from the Chandra X-ray Observatory. M82 has been observed for more than 700 ks with ACIS and an additional 190 ks with the HRC, with observations spanning the entire Chandra lifetime to date. These data paint a portrait of the complex spectral and temporal variability of the high-mass X-ray binary population of a starburst galaxy. We will discuss the properties of these sources and the impact they have on the shape of the X-ray luminosity function.

326 *AGN, QSO, Blazars VI* Oral Session *Room 607*

326.01

The History of Black Hole Accretion from X-ray Stacking

Ezequiel Treister¹, C. Urry², K. Schawinski², C. N. Cardamone², D. B. Sanders¹ ¹University of Hawaii, ²Yale University. 2:00 PM - 2:10 PM

Room 607

We take advantage of the rich multi-wavelength data available in the Chandra Deep Field South (CDF-S), including the 4 Msec Chandra observations (the deepest X-ray data to date), in order to search for heavily-obscured low-luminosity AGN among infrared-luminous galaxies. We obtained a stacked rest-frame X-ray spectrum for samples of galaxies binned in terms of their IR luminosity. We detect a significant signal at E~1 to 8 keV, which we interpret as originating from a combination of emission associated with star-formation processes at low energies and heavily-obscured AGN at E>5 keV. We further find that the relative strength of this AGN signal decays with decreasing IR luminosity, indicating

a higher AGN fraction for more luminous IR sources. The integrated intensity at high energies indicates that a significant fraction of the total black hole growth, ~22%, occurs in heavily-obscured systems that are not individually detected in even the deepest X-ray observations.

E.T. gratefully acknowledges the support provided by NASA through Chandra Postdoctoral Fellowship Award Number PF8-90055 issued by the Chandra X-ray Observatory Center, and NASA/Suzaku grant NNX09AV62G.

326.02D

AGN Triggering: New Results From The Swift Sample Of Hard X-ray Selected AGN

Michael Koss¹, R. Mushotzky¹, N. Gehrels², L. Winter³, W. Baumgartner², J. Tueller², D. Sanders⁴, E. Treister⁴, S. Veilleux¹

¹University of Maryland, ²NASA GSFC, ³University of Colorado, ⁴University of Hawaii.

2:10 PM - 2:30 PM

Room 607

Surveys of AGN taken in the optical, UV, and soft X-rays miss an important population of obscured AGN only visible in the hard X-rays and mid-IR wavelengths. Since the hard X-ray emission directly traces AGN activity, it offers the best chance to understand AGN activation. Optical imaging of this sample provides an opportunity to understand how the environments of the host galaxies are linked to AGN. We review the nature of a sample of 185 hard X-ray selected nearby (z<0.05) AGN to understand the critical link between AGN triggering, the merging process, and star formation in the host galaxy as well as multiwavelength AGN emission.

326.03

Pushing the Limit: A New & Reliable High-Redshift Emission Line Diagnostic for Separating AGNs from Star Formers

Laura Trouille¹, A. Barger², C. Tremonti³

¹Northwestern University CIERA, ²UW-Madison, U. Hawaii - IfA, ³UW-Madison.

2:30 PM - 2:40 PM

Room 607

Accurate identification of active galaxies is essential for properly assessing their impact on galaxy evolution. Classic optical emission line diagnostics for separating AGN-dominated sources from those dominated by star formation are limited to z<0.5 (e.g., in the BPT diagram, [OIII]/Hb versus [NII]/Ha, [NII] leaves the optical spectral window at z=0.5). In this talk, we present our new diagnostic based on [NeIII], [OII], and g-z color, which cleanly separates AGNs from star formers (SFs) out to z<1.4. We test our diagnostic on the SDSS DR7 galaxies. Using their BPT classification as AGNs or SFs as reference, we find that our new diagnostic reproduces the classification for 98% of the SDSS-AGNs and 96% of the SDSS-SFs. We also apply our new diagnostic to the OPTX (CDF-N, CLANS, and CLASXS) sample, a highly spectroscopically complete sample of Chandra X-ray selected AGNs. We find that all but one of our 457 X-ray selected AGNs lies in the AGN-dominated regime of our new diagnostic, while 20% would be classified as SFs using the BPT diagram (see also Winter2010 Swift-BAT results). Our new optical diagnostic thus provides a highly reliable method for distinguishing AGNs from SFs out to z<1.4. We use this new diagnostic in combination with X-ray stacking to probe sources that lie in the ambiguous region of the BPT diagram, between the AGN and SF regimes (as designated by the Kewley01 and Kauffman03 divisions). Previous optical studies suggest that these sources are SF dominated. However, we find that the stacked signal for these sources is X-ray hard, and furthermore the majority are identified as AGNs by our new diagnostic. These findings suggest that their radiation field is dominated by AGN activity, and therefore these sources should be included in AGN samples.

326.04 STIS Spectroscopy of the Central 14 pc of NGC 3998: Evidence For An Inflow Nicholas A. Devereux 1

¹Embry-Riddle Aeronautical Univ..

2:40 PM - 2:50 PM

Room 607

Prior imaging of the lenticular galaxy, NGC 3998, with the Hubble Space Telescope (HST) revealed a small, highly inclined, nuclear ionized gas disk, the kinematics of which indicate the presence of a 270 million solar mass black hole. Plausible kinematic models are used to constrain the size of the broad line region (BLR) in NGC 3998 by modeling the shape of the broad H α , H β and H γ emission line profiles. The analysis indicates that the emitting region is large with an outer radius ~ 7 pc, regardless of whether the kinematic model is represented by an accretion disk or a spherically symmetric inflow. The large size determined for the BLR in NGC 3998 is inconsistent with an extrapolation of the reverberation based BLR size - luminosity relationship defined by the broad emission lines of quasars and high luminosity AGNs. The AGN in NGC 3998 is able to sustain the ionization of the BLR, albeit with a high covering factor ranging between 20% and 100% depending on the spectral energy distribution adopted for the AGN. Furthermore, the electron temperature in the BLR is $\leq 28,800$ K consistent with photoionization by the AGN. If the gas density in the BLR is $\geq 7 \times 10^3$ cm⁻³ as indicated by the broad forbidden [S II] emission line ratio, then interpreting the broad H α emission line in terms of a steady state spherically symmetric inflow leads to a rate $\leq 6.5 \times 10^{-2}$ M \odot /yr which exceeds the requirement to explain the X-ray luminosity in terms of a radiatively inefficient inflow by a factor of ≤ 18 .

Support for Program number HST AR-11752.01-A was provided by NASA through a grant from the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, incorporated, under NASA contract NAS5-26555.

326.05

A Census of Narrow C IV Absorption Lines in 24 Quasars at Redshifts 1.9 < z < 4.6

Leah Simon¹, F. Hamann², M. Pettini³

¹Austin Peay State University, ²University of Florida, ³University of Cambridge, IoA, United Kingdom. 2:50 PM - 3:00 PM

Room 607

We present the first results from a high-resolution spectroscopic survey of 24 quasars to study the nature and origins of the narrow absorption lines (NALs) that form in quasar environments. We present 271 C IV NAL components in 136 C IV systems in 24 quasars at redshifts 1.94 < z < 4.69 between the velocity range of +5000 < v < -40000 km/s. We determine which components and systems are intrinsic to the quasar environment, that is, which lines form in the host galaxy, from the halo to the center near the quasar itself. Some of these intrinsic NALs have high velocities that limit their orgin to quasar outflows. We determine whether a NAL is intrinsic by measuring partial covering in the C IV NALs, and by looking for very broad and smooth NALs. We find that intrinsic NALs are more likely to be slightly broader (mean b = 33.6 km/s) and stronger (mean REW = 0.20 A) than their intervening counterparts (mean b = 21.2 km/s, and mean REW = 0.12 A). Several high-velocity, narrow outflows also appear in our sample. ~46% of the quasars in our sample contain at least one intrinsic NAL, with only 30% containing an intrinsic NAL within 5000 km/s of the quasar redshift. Several rich and complex C IV NAL systems are present.

326.06 Outflows in Local Seyfert 1s Detected by Swift Lisa M. Winter¹, T. Taylor¹

¹CASA/University of Colorado-Boulder. 3:00 PM - 3:10 PM

Room 607

Outflows from supermassive black holes may play a significant role in the evolution of their host galaxy. Current studies of outflows had been limited to bright nearby AGN and are therefore biased. It is therefore necessary to test the results of these studies with an unbiased AGN sample. To this end, we have searched for outflows in an unbiased sample of 44 Seyfert 1s detected in the very hard X-rays with Swift. We have jointly analyzed Suzaku/XMM-Newton and Swift BAT spectra. We detect signatures of X-ray outflows through O VII and O VIII edges, finding an outflow fraction of 40%. The sources with outflow are on average less luminous and more obscured than the sources with no outflow detection.

326.07

Reionization through Trickery: How to Find the True FUV Spectra of z>6 Quasars

Matthew O'Dowd¹, D. Schiminovich¹, R. L. Webster², Z. Haiman¹

¹Columbia University, ²University of Melbourne, Australia.

3:10 PM - 3:20 PM

Room 607

Studies of absorption in the vicinity of z > 6 quasars will enable characterization of the final stages of the epoch of reionization, and measurement of the last remnants of the neutral fraction from the cosmic dark ages. Before this can happen, we will need to know the intrinsic shape of the rest-frame FUV spectrum of luminous quasars, and in particular of the Lyman-Alpha emission line. To date, such measurements have only been possible for local, low luminosity quasars and Seyferts whose FUV spectra are not strongly absorbed in the IGM. These AGN are poor models of their high-luminosity cousins, and the BELR physics driving the Ly-alpha line may be very different. I will outline two approaches to measuring the true, unabsorbed FUV spectra of luminous quasars. First, by observing differential microlensing of strongly lensed quasars at z > 3, I will show how we can algebraically reconstruct the true FUV spectrum, and recover the absorption spectrum and measure the proximity effect to boot. Second, by targeting a narrow redshift range at $z \sim 1$, we can identify a subsample of luminous quasars that have avoided significant absorption, but are nonetheless genuine analogs of our z > 6 quasars. I will show some preliminary GALEX data of these quasars.

326.08

A Comprehensive Study of the Core of the Fe K α Emission Line in Active Galactic Nuclei Observed by the Chandra High Energy Grating

Xin Wen Shu¹, T. Yaqoob², J. Wang¹

¹University of Science and Technology of China, China, ²The Johns Hopkins University. 3:20 PM - 3:30 PM

Room 607

We present a comprehensive study of the core of the Fe K α emission line at ~6.4 keV in Active Galactic Nuclei (AGN) observed by the Chandra High Energy Grating (HEG). The sample consists of 127 observations of 46 unique sources (including 36 type 1 and 10 type 2) with z<0.3. We aim to use an empirical and uniform analysis to measure the Fe K α line centroid energy, flux, equivalent width (EW), and intrinsic width (FWHM) for both type 1 and type 2 sources. The Fe K α line is detected in 33 type 1 sources, and its centroid energy is constrained in 32 sources. We find that the distribution in the line centroid energy is strongly peaked around the value for neutral Fe, with over 80% of the observations

giving values in the range 6.38-6.43 keV. The mean equivalent width for type 1 sources was 53 ± 3 eV. The mean FWHM from the subsample of 27 sources was 2060 ± 230 km/s. From a comparison with the H β optical emission-line widths (or, for three sources, H α or Br α), we find that there is no universal location of the Fe K α line-emitting region relative to the optical BLR. However, the Fe line FWHM distribution is found to be similar for 12 type 1 and 8 type 2 objects, for which the lines are detected with adequate signal-to-noise. We also find no correlation between the line widths and the black hole masses. The results suggest the Fe K α line may arise from the same radius with respect to the gravitational radius. We confirm the presence of the X-ray Baldwin effect an anti-correlation between the Fe line EW and X-ray continuum luminosity, while HEG data have enabled isolation of this effect to the narrow core of the Fe K α line.

327

Star Associations, Star Clusters - Galactic & Extra-galactic I Oral Session *Room 606*

327.01D

Clustering of Stars in Nearby Galaxies: Probing the Range of Stellar Structures Catherine C. Kaleida $^{\rm 1}$

¹Arizona State Univ.. 2:00 PM - 2:20 PM

Room 606

Most stars form in groups and clusters. These clusters are themselves nestled within larger associations and stellar complexes. It is not yet known, however, whether stellar structures within galaxies have a bimodal or continuous size distribution. I have developed a method to uniformly select stellar groupings with sizes ranging from compact clusters (~3 pc) to stellar complexes (~200+ pc). This method was applied to the highest quality observations currently available for the nearby galaxies M51, NGC 4214, M83, and NGC 628, taken with the Hubble Space Telescope. Once groupings were identified, their sizes were measured to determine if there are preferred physical scales of clustering or if stars cluster continuously on all size scales. I have also determined the basic properties of these stellar structures, including luminosity, age, and mass. The derived properties are mapped and presented as a function of location, allowing trends in star formation history within galaxies to be explored.

This work has been supported by programs HST-AR 1068401A, HST-AR 12137, and HST-AR 11360, provided by NASA through a grant from the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS5-26555. Analysis of NGC 4214 and M83 was based on Early Release Science observations made by the WFC3 Scientific Oversight Committee. We are grateful to the Director of the Space Telescope Science Institute for awarding Director's Discretionary time for this program.

327.02

The Impact of Triple Stars on the Formation of the NGC 188 Blue Stragglers

Aaron M. Geller¹, J. R. Hurley², R. D. Mathieu³

¹Northwestern University, ²Swinburne Centre for Astrophysics and Supercomputing, Australia, ³University of Wisconsin - Madison.

2:20 PM - 2:30 PM

Room 606

We recently completed a detailed radial-velocity study of the old (7 Gyr) open cluster NGC 188 in which we identify all solar-type cluster members, and study the binaries and blue stragglers (BSs) in great detail. Using these data for guidance, we attempt to recreate the observed properties of NGC 188 within

a sophisticated N-body model. Specifically, we study how a population of primordial triples impacts the dynamical evolution of the solar-type main-sequence binary population as well as the BS production rate and mechanisms. We employ the observed main-sequence binary population of M35 (180 Myr) to set our initial binary frequency and distributions of orbital parameters. Thus we create the first N-body model whose initial binary population is defined by such detailed observations of a binary population in a young open cluster. Without any triples, the 7 Gyr main-sequence solar-type hard-binary population in the simulation matches that of NGC 188 in both frequency and distributions of orbital parameters. This simulation is also consistent with the observed spatial density profile and mass of NGC 188. However, our simulations with binaries alone cannot reproduce the large number of BSs observed in NGC 188 or their distinctive eccentricity - period distribution. Adding tertiary companions to the initial binaries produces an additional population of BSs, primarily formed through dynamical encounters that lead to direct collisions of the stars in the inner binary. Importantly, these added BSs have a high binary frequency similar to what we observe in NGC 188. Comparisons between our simulations and observations of the NGC 188 BSs place important constraints on the initial triple population, which in turn results in detailed predictions for future observations of triples in young star clusters. We suggest that dynamical encounters with triples likely played a significant role in creating the observed NGC 188 BSs.

327.03D

Relation Between field Stars And Star Clusters In Nearby Galaxies

Esteban Silva Villa¹, S. Larsen¹ ¹Utrecht University, Netherlands. 2:30 PM - 2:50 PM

Room 606

Field stars and stars clusters contain a big part of a galaxy's history, but the connection between these two systems is not clear. Even when it is commonly assumed that most stars formed in clusters, the fraction of star formation actually happening in clusters is still uncertain. We performed a systematic and homogeneous study over the galaxies NGC5236, NGC7793, NGC1313, NGC45, and NGC4395, where star clusters and field stars were analyzed separately. We provide here observational constrain on the cluster- and star formation rates. We observed that the global star formation happening in clusters varies between 1 and 10%. Our results did not show any relation between the fraction of star formation in clusters and the star formation rate density.

327.04

How To Find Stars Outside Galaxies

Duilia F. De Mello¹ ¹*CUA/NASA's GSFC.* 2:50 PM - 3:00 PM *Room 606*

I will report the latest results of our project searching for stars born in clusters outside galaxies. Very often, when galaxies collide/merge/interact, their neutral gas, HI, is stripped out of them and found in extended tidal tails in the intergalactic medium. At first glance these gas clouds look empty and even detached from the galaxies. Recently, we have found out that this is not always the case. We used the GALEX ultraviolet satellite to search within HI tails in a sample of interacting galaxies and detected several young stellar clusters and even dwarf galaxies in the process of formation. Our team (Torres-Flores et al. 2010, Urrutia-Viscarra et al. 2011) has analyzed multiwavelength data (Gemini, SDSS, VATT) of these objects showing that they are young and metal rich. Our main conclusion is that they were formed "in situ" from pre-enriched material that was ejected from the galaxies during interaction. These

nurseries can be (i) the precursors of globular clusters, (ii) dwarf galaxies in the process of formation or (iii) dissolve and not remain gravitationally bound, yielding only very sparse star streams.

327.05

Globular Cluster Contributions To The Galactic Halo: Results From Followup Studies Sarah L. Martell¹, M. Shetrone², D. K. Lai³

¹ARI, Universitaet Heidelberg, Germany, ²McDonald Observatory, UT-Austin, ³NSF Postdoctoral Fellow, UC Santa Cruz.

3:00 PM - 3:10 PM

Room 606

I will present preliminary results from two followup projects based on the Martell & amp; Grebel (2010) discovery of halo field giants that appear to have formed in globular clusters. Abundances from high-resolution spectroscopy appear to confirm the stars' in-cluster origin, and more followup spectra are being taken. We are also conducting an analogous search for CN-strong giants in the SEGUE-II data set to explore possible differences in the origins of the inner and outer halo.

327.06

Do Field OB Stars Form Alone?

M. S. Oey¹, J. B. Lamb¹, J. K. Werk¹, L. D. Ingleby¹

¹Univ. of Michigan. 3:10 PM - 3:20 PM

Room 606

We present HST/ACS observations of six field OB stars that appeared isolated in ground-based images of the Small Magellanic Cloud. Half of these targets show the statistically significant presence of a few companion stars having masses in the range 1 - 4 Msun; the remaining three targets remain candidates for OB stars that formed in true isolation, although there is a possibility that they are runaway stars. To explore the clustering parameter space occupied by our sparse clusters, we carry out Monte Carlo simulations of a cluster population based on a -2 power law distribution in the cluster membership number (N_*) or cluster mass (M_cl), plus a constant IMF. The upper-mass limits (< 100 Msun) for our observed objects generally fall within a fairly well-populated parameter space within the simulations, although this is somewhat model-dependent. Thus, the existence of these sparse groups may demonstrate that clusters with massive stars can form over a range of at least 2 - 3 orders of magnitude in M cl. This suggests that the IMF, and hence, the stellar upper-mass limit, is independent of M_cl, which bears directly on the integrated galaxy IMF (IGIMF) and theories for star formation.

328 *Stellar Populations and Kinematics of Dwarf and Irregular Galaxies* Oral Session *Room 604*

328.01

The Extended Stellar Populations of Dwarf Galaxies

Karoline Gilbert¹, B. Williams¹, P. Rosenfield¹, J. Dalcanton¹, ANGST team

¹University of Washington.

2:00 PM - 2:10 PM

Room 604

Diffuse, extended stellar populations encode information about the earliest stages of a galaxy's formation. Although most research has focused on the growth of the stellar halos of large disk galaxies like the Milky Way and Andromeda, extended envelopes of red giant branch stars have also been observed in dwarf galaxies. The extended stellar populations of low-mass galaxies are generally referred to as "halos," yet little is known about their properties (e.g., extent, profile, metallicity, and age) and origin. We use resolved stellar photometry from the Advanced Camera for Surveys (ACS) Nearby Galaxy Survey Treasury (ANGST) to study the populations dwarf galaxy halos in detail. We find that extended, old stellar populations are found in dwarf galaxies throughout the Local Volume. We present measurements of the properties of these extended stellar populations, and contrast their properties with those of the younger stellar populations in dwarf galaxies.

328.02D

Group Dynamics and Star Formation Histories from HST Observations of Nearby Galaxies

Bradley Jacobs¹, R. B. Tully¹, L. Rizzi², E. J. Shaya³

¹Univ. Of Hawaii, ²Joint Astronomy Centre, ³Univ. Of Maryland.

2:10 PM - 2:30 PM

Room 604

The several hundred galaxies that make up the Local Volume (within 10 Mpc) can be resolved into stars with the Hubble Space Telescope (HST). To date ~300 of these galaxies have been observed with HST, including a nearly complete volume-limited sample of ~150 galaxies within 4.5 Mpc. We announce the availability of a database of photometry from these observations, from which we measure distances to each galaxy based on the Tip of the Red Giant Branch (TRGB) method. Combining the TRGB distances with radial velocity information allows us to identify new members of groups and to measure group masses. Furthermore, these data can be used in the reconstruction of galaxy orbits using a numerical least-action method. Additionally, the HST photometry is well-suited to analyses of galaxy star formation histories via the color-magnitude diagram synthesis technique. This dataset, therefore, holds clues to the nature of dark matter, Large Scale Structure, and galaxy evolution. We present early results from each of these types of studies. This work is supported through HST program: GO-11584.

328.03D

Understanding the Structure of NGC 1569 and Dwarf Irregular Galaxies

Megan C. Jackson¹, D. Hunter², S. Oh³, LITTLE THINGS Team

¹Lowell Observatory/Georgia State University, ²Lowell Observatory, ³University of Cape Town, South Africa. 2:30 PM - 2:50 PM Room 604

NGC 1569 is a post-starburst dwarf irregular (dlm) galaxy located in the IC 342 galaxy group. It has 3 supermassive star clusters (SSCs) and is a well studied object in the literature. We present an in depth

study of the kinematics of the stellar and gas disks of NGC 1569 and analyze the three dimensional shape of this dlm galaxy. There are three forms of data we use to determine the shape of this system. First, we obtained long-slit, high resolution spectroscopy of the stars in NGC 1569 using the KPNO 4meter + Echelle spectrograph. For these stellar spectra, we used a filter that targets the Mg lb absorption features. During one of our 4-meter+Echelle observing runs, we changed the filter to target the [OIII] λ 5007Å emission line. Using this filter, we observed radial velocities of the ionized gas in NGC 1569, the second form of data in our study. Thirdly, we used high spatial and high spectral resolution, 21 cm, VLA HI line data obtained by THINGS. These data were mapped using a multi-scale cleaning algorithm implemented in AIPS by the LITTLE THINGS team. The kinematics of the gas were obtained using a double Gaussian decomposition method to separate a bulk motion velocity field from random, non-circular motions. In addition to the kinematic study, we also present our results of a large, 9° x 2° HI emission map made using the Robert C. Byrd Green Bank Telescope. We detect large-scale HI structure around NGC 1569 indicative of possible interactions with IC 342 galaxy group members. We conclude the dissertation talk by highlighting two more dwarf irregular galaxies for which both stellar and gas kinematics have been obtained and analyzed. This research has been funded by the NSF LITTLE THINGS grant AST-0707563 and by the NRAO Student Observing Support award GSSP10-0001.

328.04D

High Resolution, Integrated Light Abundance Analysis of Globular Clusters: The Large Magellanic Cloud Janet E. Colucci¹, R. A. Bernstein¹, A. McWilliam²

¹University of California, Santa Cruz, ²OCIW.

2:50 PM - 3:10 PM

Room 604

We present detailed chemical abundances of 21 elements in 8 clusters in the Large Magellanic Cloud (LMC). These abundances were obtained from individual absorption lines using our new method of analyzing high resolution ($R^{25,000}$) integrated-light spectra of globular clusters. We have previously used old (>10 Gvr) Milky Way clusters to demonstrate that we obtain accuracies comparable to those obtained from analysis of individual RGB stars. Here we use the LMC, which contains the necessary sample of clusters over a wide age range, to demonstrate for the first time that this abundance analysis method can be successfully applied to clusters of any age (50 Myrs to 13 Gyrs). Uniformly obtaining chemical abundances of clusters over a wide range in age allows us to investigate the chemical evolution history of the LMC in great detail. We find a spread in $[\alpha/Fe]$ at constant [Fe/H], as well as evolution of $[\alpha/Fe]$ with [Fe/H] and age. In older clusters, the light elements Na, Al, and Mg appear to be strongly affected by inter-cluster abundance variations; intermediate age and young clusters have light element abundances that are more consistent with LMC field stars. The heavy elements Ba, La, Nd, Sm, and Eu are enhanced in the youngest clusters. The heavy to light s-process ratio is elevated, ([Ba/Y] >+0.5), and increases with decreasing age, indicating a strong contribution of low-metallicity AGB star ejecta throughout the later history of the LMC. These results are consistent with prolonged, low-efficiency star formation between short bursts of more rapid star formation that resulted in massive, surviving clusters. Detailed chemical abundances measured using our new method can be obtained for galaxies within 4 Mpc using current telescopes. These abundances can be used to constrain the star formation history of galaxies in and beyond the Local Group in unprecedented detail.

328.05

Testing the Effectiveness of the H-alpha/UV flux Ratio in Determining Star Formation Rates in Dwarf Galaxies

Ferah Munshi¹, C. Christensen¹, F. Governato¹, T. Quinn¹, J. Wadsley² ¹University of Washington, ²McMaster University, Canada.

3:10 PM - 3:20 PM

Room 604

We use an N-body/smoothed particle hydrodynamic simulation to study the evolution of H-alpha and UV star formation indicators in a starbursting dwarf galaxy. H-alpha based observations of starformation under-predict the star formation rate (SFR) relative to the FUV determined SFR. The two implied scenarios: bursty star formation in dwarf galaxies or a non-uniform stellar initial mass function (IMF), cannot currently be distinguished by observation. Simulations allow us to trace star formation as stellar populations evolve, and directly measure the star formation history. In addition to being fully cosmological, with high mass resolution and a physically motivated description of star formation and feedback, our simulation is the first to correctly describe the dark matter and baryon distribution of small galaxy. Using mock multi-wavelength observations, we examine the H-alpha and UV SFRs in order to trace the evolution of the H-alpha to UV flux ratio as a function of SFR. Examining the evolution of these star formation indicators will allow us to determine whether the observed discrepancies in the fluxes could stem from the more rapid decrease of H-alpha flux from aging stellar populations.

Wednesday, January 12, 2011, 3:40 PM - 4:30 PM 329

Cannon Prize: Stellar Archaeology: New Science with Old Stars Invited Session Ballroom 6AB

329.01 Stellar Archaeology: New Science with Old Stars Anna Frebel¹

¹Harvard-Smithsonian Center for Astrophysics. Ballroom 6AB

The early chemical evolution of the Galaxy and the Universe is vital to our understanding of a host of astrophysical phenomena. Since the most metal-poor Galactic stars are relics from the high-redshift Universe, they probe the chemical and dynamical conditions as the Milky Way began to form, the origin and evolution of the elements, and the physics of nucleosynthesis. They also provide constraints on the nature of the first stars, their associated supernovae and initial mass function, and early star and galaxy formation. I will present exemplary metal-poor stars with which these different topics can be addressed. Those are the most metal-poor stars in the Galaxy ([Fe/H] < -5.0), and metal-poor stars with strong overabundances of heavy elements, in particular uranium and thorium, which can be used to radioactively date the stars to be ~13 Gyr old. I will then transition to recent discoveries of metal-poor ([Fe/H]~-3.0) stars in the least luminous dwarf satellites orbiting the Milky Way. Their stellar chemical signatures support the concept that small systems, analogous to the surviving dwarf galaxies, were the building blocks of the Milky Way's low-metallicity halo. This opens a new window for studying galaxy formation through stellar chemistry.

Wednesday, January 12, 2011, 4:30 PM - 5:20 PM

330 *Rossi Prize: Exploring the Very High Energy Sky with H.E.S.S.* Invited Session *Ballroom 6AB*

330.01

The Very High Energy Gamma Ray Sky Viewed with H.E.S.S. Werner $Hofmann^1$

¹Max-Planck-Institut fur Kernphysik, Germany.

Ballroom 6AB

This first part of the presentation serves to illustrate some of the design considerations and history behind H.E.S.S., to discuss the performance

achieved with the H.E.S.S. instrument, and in particular to present the latest state of the H.E.S.S. Galactic Plane Survey in which over 50 sources of VHE gamma rays were discovered, the majority of which now appears to be correlated with pulsar wind nebulae, but also including supernova remnants, binaries, and stellar clusters.

330.02

H.E.S.S. and Cosmic Rays Heinz Voelk¹

¹Max-Planck-Institut Fur Kernphysik, Germany.

Ballroom 6AB

A major aim of VHE astronomy is the study of relativistic particle populations in the Galaxy and elsewhere, called here the Nonthermal Universe. The physics is often described in terms of cosmic rays, even though this is a notion that emphasizes the diffuse aspect. It had been predicted that with sufficiently large imaging atmospheric Cherenkov telescopes it should be possible to study also the particle sources. And indeed, various source classes have been found. In particular individual Galactic Supernova Remnants have been for the first time localized as particle sources at multi-TeV energies by the H.E.S.S. experiment. Two examples, SNR RX J1713.7-3946 and SN 1006, will be described together with their theoretical explanation in terms of the diffusive shock acceleration process. There is an interesting complementarity to X-ray astromomy and radio continuum astronomy which also rely on mechanical energy production, and from similar sources. On a galactic scale nonthermal particle production can best be studied for starburst galaxies whose strong activity makes them detectable in VHE gamma-rays, allowing us to assess the differences between particle propagation in our Galaxy and in such energetic objects, beyond suggesting strongly that the sources are the same. Indeed, in 2009, the nearby starburst galaxies NGC 253 and M 82 have been discovered in the Northern and Southern Hemispheres by the H.E.S.S. and VERITAS telescope systems, respectively, as well as at lower gamma-ray energies by the Fermi LAT telescope in space; some of the key results will be discussed. Since galaxygalaxy mergers in galaxy clusters should lead to similar processes that should generate a strong nonthermal component there together with mass accretion, it is to be hoped that future, larger instruments will be able to turn present low upper limits into detections.

330.03 H.E.S.S. and VHE Phenomena Related to Relativistic Outflows Felix Aharonian¹

¹MPI für Kernphysik, Germany.

Ballroom 6AB

The major fraction of TeV gamma-ray emitters reported by H.E.S.S. belongs to two source populations -Pulsar Wind Nebulae (PWN) and Active Galactic Nuclei (AGN). The common aspect of the nature of these two essentially different classes of astronomical objects is their deep links to relativistic outflows realized in the forms of pulsar winds and black-hole jets. The high quality morphological, spectral and temporal studies of these objects provided by H.E.S.S. revealed a number of surprise features regarding, first of all, the efficiency of particle acceleration, in the sense of both (i) the total energy released in nonthermal forms, and (ii) maximum energy to which the individual particles are boosted. In some cases we deal with extreme machines in which the particle acceleration proceeds with maximum possible rates allowed by theory. The general properties of PWNe and AGN, as well as gamma-loud binary systems, are discussed with emphasis on their most striking features - the very high radiation efficiency of PWNe in the TeV regime and very short variability and unusually hard intrinsic energy spectra of TeV radiation of blazars.

Thursday, January 13, 2011, 8:30 AM - 9:20 AM 400

Exoplanets: New Approaches to their Discovery and Characterization Invited Session *Ballroom 6AB*

400.01 Exoplanets: New Approaches to their Discovery and Characterization Eric Agol¹

¹Univ. of Washington.

Ballroom 6AB

I review several novel approaches to exoplanet detection and characterization, including transit-timing variations (TTV), exoplanet mapping using phase variations and eclipses, and chromospheric transits. TTV may be used to characterize multi-planet systems by measuring deviations from periodicity of a transiting planet due to the gravitational pull of companion planets. As of September 2010, one example of a system with TTV has been found by the Kepler satellite, probably the first of many. In principle TTV may be used to discover companion planets, which has failed to date with ground-based telescopes, but will likely occur with Kepler. Infrared phase variations measured with Spitzer have been used to characterize the climate of hot Jupiters and to make longitudinal maps, constraining atmospheric circulation models. I will present the first eclipse map of a hot Jupiter based on Spitzer, which may be a taste of what will be done with JWST. Chromospheric transits of optically-thin emission lines should show a dip at each limb. These will have low signal-to-noise, but might be used to discover giant planets orbiting sub-giant stars. Finally, I will look well into the future towards studying planets in their habitable zones. Observations of Earth with the EPOXI satellite show that phase variations may be used to make longitudinal maps of habitable planets with continents and oceans, even in the presence of variable cloud cover. Such observations might be carried with future large space-based occulting or coronagraphic telescopes. I will conclude with some more speculative ideas on the future of planet detection and characterization.

Thursday, January 13, 2011, 9:00 AM - 2:00 PM 429 *Extrasolar Planets* Poster Session *Exhibit Hall*

429.01

How to Weigh a Star Using a Moon David M. Kipping¹

¹Harvard-Smithsonian Center for Astrophysics. Exhibit Hall

We show that for a transiting exoplanet accompanied by a moon which also transits, the absolute masses and radii of the star, planet and moon are determinable. For a planet-star system, it is well known that the density of the star is calculable from the lightcurve by manipulation of Kepler's Third Law. In an analogous way, the planetary density is calculable for a planet-moon system which transits a star, and thus the ratio-of-densities is known. By combining this ratio with the observed ratio-of-radii and the radial velocity measurements of the system, we show that the absolute dimensions of the star and planet are determinable. This means such systems could be used as calibrators of stellar evolution. The detection of dynamical effects, such as transit timing variations, allows the absolute mass of the moon to be determined as well, which may be combined with the radius to infer the satellite's composition.

429.02

Comparison Simulations of Gas Giant Planet Formation via Disk Instability

Megan K. Pickett¹, K. Cai², R. Durisen³, M. Milne¹

¹Lawrence University, ²Purdue University Calumet, ³Indiana University. Exhibit Hall

Exhibit Hall

There has been disagreement about whether cooling in protoplanetary disks can be sufficiently fast to induce the formation of gas giant protoplanets via gravitational instabilities. Simulations by our own group and others indicate that this method of planet formation does not work for disks around young, low-mass stars inside several tens of AU, while simulations by other groups show fragmentation into protoplanetary clumps in this region. To allow direct comparison in hopes of isolating the cause of the differences, we here present a comparison high-resolution three-dimensional hydrodynamics simulation of a protoplanetary disk, using an improved version of one of our own radiative schemes. We find that the disk does not fragment in our code but instead quickly settles into a state with only low amplitude nonaxisymmetric structure, which persists for at least several outer disk rotations. Further, we see no rapid radiative or convective cooling.

429.03

HD80606b Transit Observed by MOST

Jessica Roberts¹, J. W. Barnes¹, J. F. Rowe², J. J. Fortney³

¹University of Idaho, ²NASA Ames Research Center, ³University of California - Santa Cruz. Exhibit Hall

We present our results of the occultation and the full ~12 hour transit of HD80606b which we observed with the MOST (Microvariablity and Oscillations of STars) telescope. With its unusually high eccentricity of ~0.933, HD80606b challenges our understanding of the evolution of planetary systems. Due to the planet's large variance of distance from its star, the atmospheric dynamics of HD80606b are likely to be unlike any other exoplanet discovered to date. By constraining the parameters of this system, we will better understand the dynamics of this planet and will improve numerous planetary models. We

determine a best fit of the primary transit for the planetary radius, inclination, and mid-transit time. The difficulty in constraining our fits comes from several insufficiently understood parameters including mass and radius of HD80606, as well as the eccentricity, and argument of periapsis. We constrain these conflicting variables with the values determined by both Winn et al. 2009 and Hebrard et al. 2010. Hebrard et al. 2010 also noticed a mid-transit timing issue. We ran two separate fits employing the parameters determined by each paper mentioned above. We determine that our calculated mid-transit time was less than 1σ away from Hebrard et al. 2010.

429.04

Photometric Phase Variations of Long-Period Eccentric Planets

Dawn M. Gelino¹, S. R. Kane¹

¹NASA Exoplanet Science Institute, Caltech.

Exhibit Hall

The field of exoplanetary science has diversified rapidly over recent years as the field has progressed from exoplanet detection to exoplanet characterization. For those planets known to transit, the primary transit and secondary eclipse observations have a high yield of information regarding planetary structure and atmospheres. The refinement of orbital parameters allows precision targeting of transit windows and phase variations of known long-period planets which constrain the dynamics of the orbit and the geometric albedo of the atmosphere. Here we describe the expected phase function variations at optical wavelengths for long-period planets, particularly those in the high-eccentricity regime and multiple systems in resonant and non-coplanar orbits. We investigate the effects of orbital inclination on the flux ratio as it interacts with the other effects induced by orbital eccentricity. We further extend this work to the thermal detection of long-period eccentric planets during periastron passage. We apply this to the known exoplanets and discuss detection prospects and how observations of these signatures may be optimized.

429.05

A Time-dependent Mhd Simulation Of Star-planet Interaction In The Hd 189733 Planetary System **Ofer Cohen**¹, V. L. Kashyap¹, J. J. Drake¹, I. V. Sokolov², C. Garraffo¹, T. I. Gombosi² ¹Harvard-Smithsonian Center for Astrophysics, ²U. of Michigan.

Exhibit Hall

We perform a realistic simulation of Star-planet magnetic Interaction (SPI) based on the observed parameters of the HD 189733 planetary system. The simulation includes observed stellar magnetic field, stellar wind, a time-dependent planetary orbital motion and a planetary outflow. Based on the simulation's results, we find that the use of realistic stellar field results in sectors with different plasma properties in the stellar corona, where each sector crossing by the planet generates different SPI. A large reconnection event occurs when the planetary and stellar field are opposite in polarity. This reconnection event causes to a release of cold plasma from the planetary magnetosphere with significant mass flux. However, we define this flux as a magnetosphereic escape rather then atmospheric escape. In addition, the short duration of the reconnection event suggests that such SPI cannot be observed persistently, in particular when such signatures are being searched in radio bands. We also find that the total stellar mass flux carried by the stellar wind is modified during the planetary orbit, where the particular value depends on the temporal magnetic topology, and the average total stellar mass flux is reduced by the existence of the planet. A further study of SPI should involve a physical atmospheric escape from the planet, as well as the impact of stellar mass ejections on the planetary magnetosphere.

429.06 Discerning Exoplanet Migration Mechanisms Using Spin-Orbit Measurements Tim Morton¹, J. A. Johnson¹

¹Caltech.

Exhibit Hall

We investigate the current sample of exoplanet spin-orbit measurements to determine whether a dominant planet migration channel can be identified, and at what confidence. We use the predictions of Kozai migration plus tidal friction (Fabrycky & Tremaine 2007) and planet-planet scattering (Nagasawa et al. 2008) as our misalignment models, and we allow for a fraction of intrinsically aligned systems, explainable by disk migration. Bayesian model comparison demonstrates that the current sample of 32 spin-orbit measurements strongly favors a two-mode migration scenario combining planet-planet scattering and disk migration over a single-mode Kozai migration scenario. Our analysis indicates that between 34% and 76% of close-in planets (95% confidence) migrated via planet-planet scattering. Separately analyzing the subsample of 12 stars with Teff > 6250 K_which Winn et al. (2010) predict to be the only type of stars to maintain their primordial misalignments we find that the data favor a singlemode scattering model over Kozai with 85% confidence. We also assess the number of additional hot star spin-orbit measurements that will likely be necessary to provide a more confident model selection, finding that an additional 20-30 measurements has a > 50% chance of resulting in a 95%-confident model selection, if the current model selection is correct. While we test only the predictions of particular Kozai and scattering migration models in this work, our methods may be used to test the predictions of any other spin-orbit misaligning mechanism.

429.07

Search for Exoplanets Transiting Bright Stars using Existing Space-based Data

Zlatan I. Tsvetanov¹, G. Anglada-Esqude², P. McCullough³, G. Mandushev⁴, H. Markov⁵ ¹Johns Hokins University, ²Carnegie Institution of Washington, ³Space Telescope Science Institute, ⁴Lowell Observatory, ⁵National Astronomical Observatory, Bulgaria. Exhibit Hall

At the current stage of research transiting exoplanets are the only targets that allow determination of many of the key planetary parameters. In this respect the exceptionally high value of TEPs with bright parent stars is well recognized by the scientific community and several missions to perform a wide area space-based transit survey have been proposed. Here we describe a project that partially addresses this issue by using the existing data from one of the instruments on the currently operating space mission STEREO.

STEREO is the third mission in NASA's Solar Terrestrial Probes program. It uses two nearly identical spacecrafts - one on Earth-leading orbit and one on Earth-trailing orbit - each equipped with a suit of five small telescopes to provide a stereoscopic view of the coronal mass ejections as they propagate away from the Sun. As each of these telescopes observes a portion of the heliosphere, they also image the star field in the background. The continuous series of images obtained by the HI-1 instruments are well suited for searching for transiting exoplanets with bright host stars. In one orbit of the satellites the HI-1 images cover a band of $\pm 10^{\circ}$ around the ecliptic (18% of the sky). The photometric data series have the sensitivity to detect transiting hot Jupiters and other gas giants with periods up to ~20 days and even some Neptune size planets orbiting bright and/or late type stars. On the extreme bright end, the survey is sensitive to some super-Earth size planets, but the available number of target stars is small. A large number of eclipsing binaries and variable stars is also revealed.

This poster will describe the capabilities and limitations of the project and will present preliminary analysis of the existing data for RV discovered planets and an interesting eclipsing binary system.

429.08

A Search For Transits Of GJ 581c And GJ 581e Using MOST Space-based Observations

Diana Dragomir¹, J. Matthews¹, J. Rowe², HARPS team

¹University of British Columbia, Canada, ²NASA/Ames.

Exhibit Hall

We have searched MOST space-based photometry for transits of super-Earths GJ 581c and GJ 581e. The nearly continuous observations span ~3 orbital periods for each of the two planets. We place upper limits on the radii of both companions. For edge-on orbital inclinations, we rule out a wide range of interior models in the case of GJ 581c, and the lowest density interior models for GJ 581e. We present the results of our analysis as well as an assessment of photometric variability for GJ 581.

429.09

The Planet in the HR 7162 Binary System Discovered by PHASES Astrometry

Matthew W. Muterspaugh¹, B. F. Lane², M. Konacki³, B. F. Burke⁴, M. M. Colavita⁵, M. Shao⁵, W. I. Hartkopf⁶, A. P. Boss⁷, J. O'Connell¹, F. C. Fekel¹, S. J. Wiktorowicz⁸

¹Tennessee State University, ²Draper Laboratory, ³Nicolaus Copernicus Astronomical Center, Polish Academy of Sciences, Poland, ⁴MIT, ⁵JPL, ⁶USNO, ⁷Carnegie Institution of Washington, ⁸UC Berkeley. Exhibit Hall

The now-completed Palomar High-precision Astrometric Search for Exoplanet Systems (PHASES) used phase-referenced long-baseline interferometry to monitor 51 binary systems with 35 micro-arcsecond measurement precision, resulting in the high-confidence detection of a planet in the HR 7162 system. The 1.5 Jupiter mass planet is in a ~2 AU orbit around one of the stars, whereas the binary itself has a separation of only ~19 AU. Despite the close stellar companion, this configuration is expected to be stable, based on dynamic simulations. In the context of our solar system, this is analogous to a Jovian planet just outside of Mars' orbit, with a second star at the distance of Uranus. If this configuration were present during the period of planet formation, the complex gravitational environment created by the stars would seem to disrupt planet formation mechanisms that require long times to complete (thousands of years or more). While it is possible the arrangement resulted from the planet being formed in another environment (a single star or wider binary) after which the system reached its current state via dynamic interactions (star-planet exchange with a binary, or the binary orbit shrinking by interacting with a passing star), the frequency of such interactions is very low. Because the PHASES search only had the sensitivity to rule out Jovian mass companions in 11 of our 51 systems, yet one such system was found, the result indicates either extreme luck or that there is a high frequency of ~20 AU binaries hosting planets. The latter interpretation is supported by previous detections of planets in 5-6 additional ~20 AU binaries in other surveys (though with less control over the statistics for determining frequency of occurrence). Thus, there is observational support suggesting that a mechanism for rapid Jovian planet formation occurs in nature.

429.10

SEEDS of Exoplanetary Science at the Subaru Telescope

Michael W. McElwain¹, SEEDS collaboration

¹*Princeton University.*

Exhibit Hall

The Subaru Strategic Exploration of Exoplanets and Disks Survey (SEEDS) is the first strategic observing program (SSOPs) awarded by the National Astronomical Observatory of Japan (NAOJ). This survey has been awarded 120 nights over five years time to use the new high contrast imaging system to study exoplanets through direct detection, explore the evolution of protoplanetary and debris disks, and investigate the link between exoplanets and circumstellar disks. Less than one year of survey operations

have elapsed up to this point. In this poster we describe the overall survey architecture and recent exoplanet and disk results from this large, international survey.

430

Galaxies, Galaxy Clusters and Friends Poster Session *Exhibit Hall*

430.01

Luminous Satellites of Early-Type Galaxies I: Spatial Distribution

Anna Nierenberg¹, M. W. Auger¹, T. Treu¹, P. J. Marshall², C. D. Fassnacht³ ¹UCSB, ²Oxford, United Kingdom, ³UCD.

Exhibit Hall

We study the spatial distribution of faint satellites of intermediate redshift (z between 0.1 and 0.8) early-type galaxies, selected from the GOODS fields. We combine high resolution HST images and stateof-the-art host subtraction techniques to detect satellites of unprecedented faintness and proximity to intermediate redshift host galaxies (up to 5.5 magnitudes fainter and as close as 0.5 arcseconds/2.5 kpc to the host centers). We model the spatial distribution of objects near the hosts as a combination of an isotropic, homogenous background/foreground population and a satellite population with a power law radial profile and an elliptical angular distribution. We detect a significant population of satellites with Ns=1.7 (+0.9,-0.8) that is comparable to the number of Milky Way satellites with similar host-satellite contrast. The average projected radial profile of the satellite distribution is isothermal with power gamma_p=-1.0 (+0.3,-0.4), which is consistent with the observed central mass density profile of massive early-type galaxies. Furthermore, the satellite distribution is highly anisotropic (isotropy is ruled out at a greater than 99.99% confidence level). Defining phi to be the offset between the major axis of the satellite spatial distribution and the major axis of the host light profile, we find a maximum posterior probability of phi=0 and phi less than 42 degrees at the 68% confidence level.

430.02

The Chemical Evolution of Milky Way Satellite Galaxies from Keck/DEIMOS Multi-Element Abundance Measurements

Evan Kirby¹

¹California Institute of Technology.

Exhibit Hall

The dwarf spheroidal (dSph) satellite galaxies of the Milky Way make good subjects for testing chemical evolution models because they contain many stars bright enough for medium-resolution spectroscopic campaign of eight Milky Way dSphs has produced a catalog of nearly 3000 stars with spectral synthesis-based abundance measurements of Fe and the alpha elements Mg, Si, Ca, and Ti. Maximum likelihood fits of analytic chemical evolution models to the eight metallicity distributions show that the histories of the less luminous dSphs were marked by massive amounts of gas loss. The average [α /Fe] ratios for all dSphs follow roughly the same path with increasing metallicity. There is little evidence of the predicted knees in the [α /Fe] vs. [Fe/H] diagram, corresponding to the metallicity at which Type Ia supernovae begin to explode. Instead, Type Ia supernova ejecta contribute to the abundances of all but the most metal-poor ([Fe/H] < -2.5) stars. Finally, a new numerical chemical evolution model tracks elemental abundance patterns, star formation rate, Types II and Ia supernova explosions, and supernova feedback. Similar to the analytic models, the numerical models reveal that the star formation history of a dSph is a strong function of its present-day luminosity, but not velocity dispersion, half-light radius, or Galactocentric distance.
Massive Star Feedback and the Evolution of the Blue Compact Dwarf Galaxy NGC 2537 Elise Larson¹, E. M. Wilcots¹

¹University of Wisconsin-Madison Astronomy Department.

Exhibit Hall

The nearby Blue Compact Dwarf galaxy NGC 2537 is a small irregular galaxy. We find that the C and X band radio continuum emission is dominated by a large supernova complex. Our study of the distribution and kinematics of the HI content of NGC 2537 show it to have extended spiral structure, but an inner region that is more irreuglar in its distribution of gas. We model the rotation curve and velocity field of NGC 2537 and fit both with a range of mass models. We present our results in the context of measuring the effects of stellar feedback on the distribution and kinematics of gas within the galaxy.

430.04

Discovery of a Candidate Compact Elliptical Galaxy with SOAR/SOI

Claire M. Davy¹, R. Marzke¹, S. Pehrson¹, Z. Hoch¹, M. Maia², L. N. da Costa², P. Pellegrini² ¹San Francisco State University, ²Observatório Nacional, Brazil. Exhibit Hall

Compact elliptical galaxies are extremely rare objects that populate a puzzling gap in the range of structural parameters of spheroidal galaxies. It is unclear whether they share a common origin with their giant-elliptical cousins or represent a separate population with a physically different formation history. As part of an ongoing search for compact elliptical galaxies, we analyzed ugiz imaging of the regions around ten bright elliptical galaxies to search for compact companions. The images were taken at SOAR using the SOAR Optical Imager. These observations represent the first stage of the SOAR Ultracompact Dwarf Survey (SUDS), which uses optical and infrared colors to distinguish nearby compact ellipticals from foreground stars and background galaxies. Our analysis of the SOAR photometry has identified a candidate compact elliptical galaxy located approximately 36 kpc in projection from the bright elliptical galaxy NGC1653. Further SOAR data will constrain the redshift, velocity dispersion, chemical composition, and dark matter content of this rare relic of early galaxy formation.

430.05

Super-resolving Compact, Massive Early-type Galaxies Matt Auger¹

¹UC Santa Barbara.

Exhibit Hall

The massive compact objects ('red nuggets') recently discovered at z > 1.5 appear to have disappeared in the local Universe and theoretical models of galaxy evolution are unable to explain where they have gone. The case is dire: either the models are wrong or the observations are being misinterpreted. One promising way forward is to find and study red nuggets at lower redshifts where, for example, extended low-surface brightness envelopes can be observed. I will present results from a pilot program to find and study intermediate-redshift analogs to the high-redshift red nuggets. These new red nuggets are earlytype background sources of strong gravitational lens systems (the foreground galaxies are also earlytypes, so these are early-type/early-type lenses, or EELs), and I exploit the magnification of lensing and adaptive optics imaging to investigate these compact galaxies with approximately 200 pc resolution.

Calibrated Tully-fisher Relations For Improved Photometric Estimates Of Disk Rotation Velocities Reinabelle Reyes¹, R. Mandelbaum¹, J. E. Gunn¹, J. Pizagno²

¹*Princeton University,* ²*University of Washington.*

Exhibit Hall

We present calibrated scaling relations (also referred to as Tully-Fisher relations or TFRs) between rotation velocity and photometric quantities-- absolute magnitude, stellar mass, and synthetic magnitude (a linear combination of absolute magnitude and color)-- of disk galaxies at z~0.1. First, we selected a parent disk sample of ~170,000 galaxies from SDSS DR7, with redshifts between 0.02 and 0.10 and r band absolute magnitudes between -18.0 and -22.5. Then, we constructed a child disk sample of 189 galaxies that span the parameter space-- in absolute magnitude, color, and disk size-- covered by the parent sample, and for which we have obtained kinematic data. Long-slit spectroscopy were obtained from the Dual Imaging Spectrograph (DIS) at the Apache Point Observatory 3.5 m for 99 galaxies, and from Pizagno et al. (2007) for 95 galaxies (five have repeat observations). We find the best photometric estimator of disk rotation velocity to be a synthetic magnitude with a color correction that is consistent with the Bell et al. (2003) color-based stellar mass ratio. The improved rotation velocity estimates have a wide range of scientific applications, and in particular, in combination with weak lensing measurements, they enable us to constrain the ratio of optical-to-virial velocity in disk galaxies.

430.07

3C390.3: Variability And Black Hole Mass

Matthias Dietrich¹, B. M. Peterson¹, C. Grier¹

¹The Ohio State University.

Exhibit Hall

To measure the mass of central super-massive black holes in Active Galactic Nuclei (AGN) which is a fundamental parameter to understand the physics of AGN and is of great interest to follow the evolution of galaxies, the study of AGN variability has been established as a powerful tool to achieve those goals. The delayed response of broad emission line fluxes in the optical and in the ultraviolet wavelength domain to variations of the continuum strength provides, in combination with the velocity of the line emitting gas, a direct measurement of the size of the line-emitting region and hence of the black hole mass. We will present results of an optical monitoring campaign for 3C390.3 using the 2.4m Hiltner Telescope at MDM Observatory. We measured g-band flux variations, as well as the variability of the broad Ha6563, Hb4861, Hg4340, HeI5876, and HeII4686 emission line fluxes and of the optical continuum flux F(5100). Applying reverberation mapping analysis we find that the emission line variations are delayed with respect to the variable continuum by t = 40 days to 50 days. The lack of delay between the response to the blue and red parts of the profiles supports orbital motion as dominant motion of the gas. Applying the virial theorem we find a mass of Mbh = $2x 10^{8}$ Msol for the SMBH of 3C390.3. Combining this with the information of the inclination of the line emitting disk-like structure yields a black hole mass which is consistent with mass estimates based on stellar dynamics. This work has been supported by the NSF through grant AST-0605066.

430.08

Accretion Rate: An Axis Of Agn Unification

Jonathan R. Trump¹, C. D. Impey², B. C. Kelly³ ¹UC Santa Cruz, ²Arizona, ³CfA.

Exhibit Hall

We show how accretion rate governs the physical properties of broad-line, narrow-line, and lineless active galactic nuclei (AGNs). We avoid the systematic errors plaguing previous studies of AGN accretion

rate by using accurate accretion luminosities from well-sampled multiwavelength SEDs from the Cosmic Evolution Survey (COSMOS), and accurate black hole masses derived from virial scaling relations (for broad-line AGNs) or host-AGN relations (for narrow-line and lineless AGNs). In general, broad emission lines are present only at the highest accretion rates (L/L_Edd>0.01), and these rapidly accreting AGNs are observed as broad-line AGNs or possibly as obscured narrow-line AGNs. Narrow-line and lineless AGNs at lower specific accretion rates (L/L_Edd<0.01) are unobscured and yet lack a broad line region. The disappearance of the broad emission lines is caused by an expanding radiatively inefficient accretion flow (RIAF) at the inner radius of the accretion disk. The presence of the RIAF also drives L/L_Edd<0.01 narrow-line and lineless AGNs to be 10-100 times more radio-luminous than broad-line AGNs, since the unbound nature of the RIAF means it is easier to form a radio outflow. The IR torus signature also tends to become weaker or disappear from L/L_Edd<0.01 AGNs, although there may be additional mid-IR synchrotron emission associated with the RIAF. Together these results suggest that specific accretion rate is an important physical "axis" of AGN unification, described by a simple model.

430.09

The Host Galaxies of Circumnuclear Water Masers

Ingyin Zaw¹, G. Zhu², M. Blanton², L. Greenhill³

¹New York University Abu Dhabi, ²New York University, ³Harvard-Smithsonian Center for Astrophysics. Exhibit Hall

We study the optical properties of the host galaxies of extragalactic circumnuclear water masers. We cross-match the galaxies surveyed for nuclear water maser emission with the SDSS low-z galaxy sample with redshift z<0.05 in the NYU-VAGC catalog and find that the detection rate of masers is higher at higher optical luminosity, larger velocity dispersion, and higher [OIII] lambda 5007 luminosity. We discuss the possible physical explanations and implications for future surveys.

430.10

Calibrating High-z Black Hole Mass Estimators Using The FMOS Near-IR Spectra

Jong-Hak Woo¹, P. Kim¹, C. Onken², T. Nagao³, C. Kochanek⁴, J. Kollmeier⁵, S. Kim⁶ ¹Seoul National University, Korea, Republic of, ²ANU, Australia, ³Ehime University, Japan, ⁴OSU, ⁵Carnegie, ⁶KASI, Korea, Republic of.

Exhibit Hall

Using the newly commisoned Fiber-Multi-Object-Spectrograph at the Subaru telescope, we obtained near-IR spectra of a sample of 17 quasars at 0.6 < z < 2.6, selected from the NOAO Deep Wide-Field Survey (NDWFS) Bootes field, in order to calibrate high-z black hole mass (MBH) estimators. MBHs are generally determined through the kinematics of ionized gas clouds around the black hole assuming virial equilibrium. The velocity profiles of Hbeta/Halpha, Mg II and C IV are used to infer the gas kinematics of low-z, mid-z, and high-z quasars, respectively. However, the MBHs based on MgII and CIV are not very well calibrated. We compare the Hbeta/Halpha-based MBH estimates from the new FMOS near-IR spectra, with the CIV/MgII-based MBH estimates from our existing optical spectra, and present a new calibration of MBH estimators.

Dust and Molecular Gas from the Optically Faint Quasars at z~6

Ran Wang¹, C. Carilli², R. Neri³, D. Riechers⁴, J. Wagg⁵, F. Walter⁶, F. Bertoldi⁷, A. Omont⁸, P. Cox³, K. Menten⁹, X. Fan¹, M. Strauss¹⁰

¹University of Arizona, ²NRAO, ³IRAM, France, ⁴Caltech, ⁵ESO, Chile, ⁶MPIfA, Germany, ⁷University of Bonn, Germany, ⁸IAP, France, ⁹MPIfR, Germany, ¹⁰Princeton University. Exhibit Hall

We present millimeter observations of the twelve z~6 guasars discovered from the SDSS southern survey. These objects are typically one or two magnitudes fainter in the optical (i.e., 20.6 <z AB<22.3) than the optically bright z~6 quasar sample selected from the SDSS main survey. We observed the 250 GHz dust continuum emission from these objects using the Max Plank Millimeter Bolometer Array (MAMBO) on the IRAM-30m telescope and three of them have been detected. We also searched for Molecular CO (6-5) line emission in the three MAMBO detections with the IRAM Plateau de Bure Interferometer and two of them have been detected. The millimeter continuum and CO detections in the optically faint quasars at z~6 reveal strong FIR emission from 40 to 60 K warm dust and highly excited molecular gas in the quasar host galaxies. The molecular gas masses of the two CO detections are all about 10^10 Msun, which are comparable to that of the CO-detected optically bright quasars at z^{-6} . Their FIR-to-CO luminosity ratios are also consistent with that of the previous CO-detected quasars at z^2 to 6 and the dusty starbusrt systems, e.g., the submillimeter galaxies. However, their FIR-to-UV luminosity ratios are higher than that of the millimeter-detected optically bright quasars at z~6. This confirms the shallow nonlinear FIR-to-AGN luminosity relationship found with other AGN-starburst systems at local and high-z universe. All these results suggest massive star formation coeval with rapid black hole accretion in the host galaxies of the millimeter-detected optically faint quasars at z~6. Further high-resolution imaging of the Molecular CO emission (e.g., with ALMA) will be important to measure the dynamical masses of the spheroidal hosts and understand the black hole-bulge relationship of the optically faint guasars at the earliest epoch.

430.12

A Candidate Binary Black Hole System at z=1.175

Robert S. Barrows¹, D. Stern², K. K. Madsen³, F. A. Harrison³, M. C. Cushing², C. D. Fassnacht⁴, R. L. Griffith³, A. H. Gonzalez⁵, J. D. Kirkpatrick³, D. J. Lagattuta⁴

¹University of Arkansas, ²Jet Propulsion Laboratory, California Institute of Technology, ³California Institute of Technology, ⁴University of California at Davis, ⁵University of Florida. Exhibit Hall

We discuss properties of the X-ray source CXOXBJ142607.6+353351 (CXOJ1426+35) which shows double rest-frame optical/UV emission lines, separated spatially by 0.68 arcseconds and in velocity-space by 700 km/s. Emission line ratios in both systems indicate ionization by an AGN continuum, and the double-peaked profile resembles the optical spectrum of many candidate binary AGN. However, other physical processes involving complex gas kinematics may produce the double peaks. To better understand the source, we have also acquired near infrared (NIR) adaptive optics (AO) imaging and NIR slit spectroscopy and have analyzed available archival data. The AO image reveals only a single nucleus, implying that either there is only a single AGN present, or the second AGN is highly obscured. Interestingly, significant obscuration is consistent with the high level of extinction inferred from the X-ray data. CXOJ1426+35 may also represent the case of two narrow line regions (NLRs) present as the result of a recent merger, with each illuminated by a single AGN, or NLR clouds driven by an outflow from an accretion disk. Furthermore, that the source is radio-quiet argues strongly against any sort of jet-cloud interaction. Developing a clear understanding of the physical process producing the complex emission line profiles

seen in CXOJ1426+35 and other sources is important to both the search for dual/binary SMBHs and the study of quasar/AGN emission line regions.

430.13

Ten Thousand X-ray Emitting AGN From ROSAT And SDSS

Breanna A. Binder¹, W. Voges², B. Margon³, S. F. Anderson¹, R. M. Plotkin⁴, D. Haggard⁵, B. F. Williams¹ ¹University of Washington, ²Max Planck Institut fur extraterrestrische Physik, Germany, ³University of California, Santa Cruz, ⁴University of Amsterdam, Netherlands, ⁵Northwestern University. Exhibit Hall

We present further results of an extensive program to optically identify quasars and other AGN detected as X-ray sources. Identifications are made via a combination of X-ray data from the ROSAT All-Sky Survey (RASS) and optical imaging and spectroscopic data from the Sloan Digital Sky Survey (SDSS) Data Release 7 (DR7). These RASS/SDSS data provide an expanded catalog of approximately ten-thousand confirmed quasars and other AGN, across a broad redshift and luminosity range, that are likely RASS X-ray sources identifications. As part of this expanded catalog, we identify thousands of AGN exhibiting narrow permitted emission lines (including narrow-line Seyfert 1 candidates), as well as hundreds of X-ray emitting BL Lac candidates. Identifications as X-ray sources are statistically secure, with only a few percent likely to be random superpositions. We use our large sample of X-ray identifications to consider rare and interesting subsets of AGN, and to investigate the overall relationship between X-ray and optical luminosities in quasars/AGN.

430.14

Breaking the Connection Between Starbursts and AGN: A Spitzer Spectroscopic Study of Powerful Radio-Galaxies</b

Daniel Dicken¹

¹*Rochester Institute of Technology.*

Exhibit Hall

We have conducted a deep Spitzer IRS survey of the complete 2Jy sample of 46 radio loud-AGN and a sample of 19 3CRR sources, obtaining a 94% and 79% completion rate for the 2Jy and 3CRR samples respectively. The aim of this spectroscopic campaign was to investigate the abundance of young stellar populations using starburst tracing PAH features within the spectra. Our analysis reveals these tracers in only a minority of objects (20%). From the wealth of complementary data available for the 2Jy sample and 3CRR samples we are able to provide a comprehensive analysis of a range of different starburst tracing techniques. The conclusive results provides statistically significant evidence that the majority of radio-loud AGN (0.03<z<0.7) do not have young star formation, finding a maximum of 25% of the objects with strong evidence for starburst. It has been suggested that Radio-loud AGN could be triggered at the peak of major gas rich mergers and such a merger would induce contemporary starburst activity. Given that the life times of radio activity and starburst are thought to be similar, the lack of young stellar populations in our radio galaxy samples argues against such a triggering event for the radio source. Here we will present our results and discuss the consequences for our understanding of the triggering and evolution of powerful radio galaxies.

430.15

The Rest Frame Ultraviolet Composite Spectrum of UV-Selected Active Galactic Nuclei at z~2-3 Kevin Hainline¹, A. E. Shapley¹, J. E. Greene², C. C. Steidel³

¹UCLA, ²University of Texas, Austin, ³California Institute of Technology. Exhibit Hall

We present new results for a sample of 33 narrow-lined UV-selected active galactic nuclei (AGNs), identified in the course of a spectroscopic survey for star-forming galaxies at $z \sim 2-3$. The rest-frame UV

composite spectrum for our AGN sample shows several emission lines characteristic of AGNs, as well as interstellar absorption features seen in star-forming Lyman Break Galaxies (LBGs). The UV continuum slope of the composite spectrum is significantly redder than that of a sample of non-AGN UV-selected star forming galaxies. Blueshifted SilV absorption provides evidence for outflowing highly-ionized gas in these objects at speeds of 10^(3) km/s, quantitatively different from what is seen in the outflows of non-AGN LBGs. Grouping the individual AGNs by parameters such as Ly-alpha equivalent width, redshift, and UV continuum magnitude allows for an analysis of the major spectroscopic trends within the sample. Stronger Ly-alpha emission is coupled with weaker low-ionization absorption, which is similar to what is seen in the non-AGN LBGs, and highlights the role that cool interstellar gas plays in the escape of Ly-alpha photons. However, the AGN composite does not show the same trends between Ly-alpha strength and extinction seen in the non-AGN LBGs. These results represent the first such comparison at high-redshift between star-forming galaxies and similar galaxies that host AGN activity.

430.16

Quasar Selection Based On Photometric Variability

Chelsea MacLeod¹, K. Brooks¹, Z. Ivezic¹, C. S. Kochanek², R. Gibson¹, A. Meisner¹, S. Kozlowski², B. Sesar¹, A. C. Becker¹, W. H. deVries³

¹University of Washington, ²The Ohio State University, ³University of California. Exhibit Hall

We develop a method for separating quasars from other variable point sources using SDSS Stripe 82 light curve data for ~10,000 variable objects. To statistically describe quasar variability, we use a damped random walk model parametrized by a damping time scale, tau, and an asymptotic amplitude (structure function), SF inf. With the aid of an SDSS spectroscopically confirmed guasar sample, we demonstrate that variability selection in typical extragalactic fields with low stellar density can deliver complete samples with reasonable purity (or efficiency, E). Compared to a selection method based solely on the slope of the structure function, the inclusion of the tau information boosts E from 60% to 75% while maintaining a highly complete sample (98%) even in the absence of color information. With the aid of color selection, the purity can be further boosted to 96%, with C=93%. Hence, selection methods based on variability will play an important role in the selection of quasars with data provided by upcoming large sky surveys, such as the Large Synoptic Survey Telescope (LSST). For a typical (simulated) LSST cadence over 10 years and a photometric accuracy of 0.03 mag (achieved at i~22), C is expected to be 88% for a simple sample selection criterion of tau>100 days. In summary, given an adequate survey cadence, photometric variability provides an even better method than color selection for separating guasars from stars. We acknowledge support by NSF grant AST-0807500 to the University of Washington.

430.17

Spectral Survey of X-Ray Bright Active Galactic Nuclei from the Rossi X-ray Timing Explorer Elizabeth Rivers¹, A. Markowitz¹, R. Rothschild¹

¹UCSD.

Exhibit Hall

Using long-term monitoring data from the Rossi X-ray Timing Experiment (RXTE), we have selected 23 active galactic nuclei (AGN) with sufficient brightness and overall observation time to derive broadband X-ray spectra from 3 to >100 keV. Our sample includes mainly radio-quiet Seyferts, as well as seven radio-loud sources. Given the longevity of the RXTE mission, the greater part of our data is spread out over more than a decade, providing truly long-term average spectra and eliminating inconsistencies arising from variability. We present long-term average values of absorption, Fe line parameters, Compton reflection strengths and photon indices, as well as fluxes and luminosities for the hard and

very hard energy bands, 2-10 keV and 20-100 keV respectively. We find tentative evidence for high energy rollovers in three of our objects. We improve upon previous surveys of the very hard X-ray energy band in terms of accuracy and sensitivity, particularly with respect to confirming and quantifying the Compton reflection component. This survey is meant to provide a baseline for future analysis with respect to the long-term averages for these sources and to cement the legacy of RXTE, and especially its High Energy X-ray Timing Experiment, as a contributor to AGN spectral science.

430.18

Geometric and Dynamical Models of Reverberation Mapping Data

Anna Pancoast¹, B. Brewer¹, T. Treu¹

¹University of California Santa Barbara.

Exhibit Hall

We present a general method to analyze reverberation mapping data that provides both estimates for the black hole mass and for the geometry and dynamics of the broad line region (BLR) in active galactic nuclei (AGN). Our method directly infers the spatial and velocity distribution of the BLR from the data, allowing us to easily derive a velocity-resolved transfer function and allowing for a self-consistent estimate of the black hole mass without a virial coefficient. We obtain estimates and reasonable uncertainties of the BLR model parameters by implementing Markov Chain Monte Carlo and Nested Sampling algorithms using the formalism of Bayesian probability theory. We use Gaussian Processes to interpolate the the continuum light curve data and create mock light curves that can be fitted to the data. We test our method by creating simulated reverberation mapping data-sets with known true parameter values and by trying to recover these parameter values using our models. We are able to recover the parameters with realistic uncertainties that depend upon the variability of the AGN and the quality of the reverberation mapping campaign.

430.19

Active Galactic Nuclei Variability With Wide-Field Infrared Survey Explorer (WISE)

Sam Koshy¹, D. Hoffman², R. M. Cutri²

¹California State University, Long Beach, ²Infrared Processing and Analysis Center / California Institute of Technology.

Exhibit Hall

A large fraction of objects in the universe vary in brightness as a function of time. Whereas Kozlowski et al. (2010) investigated a large sample of variable AGN with the Spitzer Space Telescope in the mid-IR for the first time, the WISE telescope can probe AGN variability at much shorter time scales, ranging from hours to months. Also, WISE is an all-sky survey, and thereby provides a much larger catalogue of infrared sources to analyze. A comprehensive list of quasi-stellar objects was generated using the NASA/IPAC Extragalactic Database. The light curves of these 132,851 objects were obtained using WISE observations and the standard deviation of the flux for each object was calculated. We consider sources in different variability levels where these variability levels correspond to the objects' deviation from the median standard deviation values of the light curve. In addition, we compute the variability of the objects over different time scales and compare the results to Kozlowski et al. (2010) to observe how variability of AGNs evolve over a period of hours to months. We present light curves of time.

Emission from Hot Dust in the Infrared Spectra of Gamma-ray Bright Blazars

Michael Malmrose¹, A. P. Marscher¹, S. G. Jorstad¹, R. Nikutta², M. Elitzur² ¹Boston University, ²University of Kentucky.

Exhibit Hall

A possible source of γ -ray photons observed from the jets of blazars is inverse Compton scattering by relativistic electrons of infrared seed photons from a hot, dusty torus in the nucleus. We use observations from the Spitzer Space Telescope to search for signatures of dust in the infrared spectra of four γ -ray bright blazars, the quasars 4C21.35, CTA102, and PKS 1510-089, and the BL Lacertae object ON231. The spectral energy distribution (SED) of the quasar 4C 21.35 contains a prominent infrared excess indicative of dust emission. After subtracting a non-thermal component with a power-law spectrum, we fit a dust model to the residual SED. The model consists of a blackbody with temperature ~ 1200 K, plus a much weaker optically thin component at ~ 660 K. The total luminosity of the thermal dust emission is ~ 7.9(2)E+45 erg/s . If the dust lies in an equatorial torus, the density of IR photons from the torus is sufficient to explain the γ -ray flux from 4C21.35 as long as the scattering occurs within a few parsecs of the central engine. Upper limits to the luminosity from thermal emission from dust in CTA102, PKS 1510-089, and ON231, are 1.1E+46 , 2.3E+45 , and 6.6E+43 erg/s , respectively. The covering factor of the hot dust in 4C 21.35, ~32%, is similar to non-blazar quasars, however 4C 21.35 is deficient in cooler dust. This could be the result of either ultraviolet emission from the jet heating the outer portions of the dust torus.

430.21

Flux Monitoring of Intraday Variable Sources with KVN Yonsei Radio Telescope

Jeewon Lee¹, B. W. Sohn², D. Y. Byun², J. Lee², P. Park², M. Kim³, S. S. Kim¹ ¹Kyunghee Univ., Korea, Republic of, ²KASI, Korea, Republic of, ³Sejong Univ., Korea, Republic of. Exhibit Hall

We present the results of flux monitoring of BL Lac object 0716+71 and 0954+65 at 22 GHz and 43 GHz. Both of the flat spectrum radio sources are known as Intraday variables (IDVs) which are characterized by fast flux variation on time scales of a day or less. In general, the IDV phenomenon is interpreted as the effect of refractive scintillation in the interstellar medium or the evidence of source intrinsic flux variation. In order to study emission mechanism of IDV sources, the observations were made simultaneously at 22GHz and 43GHz with KVN Yonsei 21m radio telescope.

430.22

The HST GOODS NICMOS Survey: The Formation of Massive Galaxies

Asa Bluck¹, C. J. Conselice², F. Buitrago², GNS Team

¹Gemini Observatory, ²University of Nottingham, United Kingdom. Exhibit Hall

The GOODS NICMOS Survey is a large Hubble Space Telescope survey which images 1/6 the area of the total GOODS fields in the near infrared (H-band). It obtains unprecedented depth and area coverage, centering its 180 orbits (and 60 pointings) around the most massive galaxies in the Universe at $z \sim 1.5$ - 3. At these redshifts we observe rest-frame optical light and can therefore resolve to relatively high resolution the established stellar populations of massive galaxies at very early times in the Universe's history. We present the major merger histories of these massive galaxies, finding that the fraction of merging massive galaxies rises monotonically with redshift out to at least $z \sim 3$. Furthermore, we also investigate the size evolution of massive galaxies noting that massive galaxies at high redshifts were substantially smaller in effective radii, for their stellar masses, than local galaxies. We observe that the major merger fraction for massive galaxies drops by an order of magnitude from z = 3 to the present,

during which time the sizes of these objects grow by up to a factor of 5. This creates a paradox in which galaxies grow most when merging and interacting the least. We offer a tentative solution to this apparent mystery by evoking a potent mix of AGN feedback and minor mergers. This research was funded my the STFC and NASA/STSci grant HST-GO11082.

430.23

Extreme Star Formation and AGN Activity in a Massive Protocluster at z=5.3

Peter L. Capak¹, D. Riechers¹, N. Scoville¹, C. Carilli², P. Cox³, R. Neri³, M. Salvato⁴, E. Schinnerer⁵, L. Yan¹, G. W. Wilson⁶, M. Yun⁶, F. Civano⁷, M. Elvis⁷, A. Karim⁸, B. Mobasher⁹, J. G. Staguhn¹⁰ ¹Caltech, ²NRAO, ³IRAM, France, ⁴MPIPP, Germany, ⁵MPIA, Germany, ⁶UMass, ⁷CFA, ⁸MIPA, Germany, ⁹University of California, Riverside, ¹⁰Goddard Space Flight Center. Exhibit Hall

We report the discovery and spectroscopic confirmation of a massive (>4x10^11) proto-cluster at z=5.3 in the COSMOS field. The proto-cluster extends over >13 Mpc and contains an >11 times over-density of L>L* Lyman-break galaxies at its core. This region contains both a luminous x-ray detected quasar and an extreme star-bursting galaxy containing a significant reservoir of cold molecular gas. This object provides the first opportunity to study the early phases of galaxy cluster formation.

430.24

Probing Extreme-EW Lyman-α Emitting Galaxy Populations Using A Broad Band Selection Technique. Brian J. Baptista¹, D. Bonfield², C. Grady³, D. Lindler³, S. Mufson¹, B. Woodgate³

¹Indiana University, ²University of Hertfordshire, United Kingdom, ³NASA/Goddard Space Flight Center. Exhibit Hall

The emission mechanisms that drive extreme-EW Lyman- α emitting galaxies (LAEs), though studied for the last decade, still are not well understood. The explanation for their pronounced Lyman- α emission has ranged from population III stars, to obscured AGN, to collapsing gas clouds. Since only a small number of these systems have been studied in depth, it is unknown whether or not LAEs are simply a stage in typical galaxy evolution or a rare and more peculiar phenomenon. Most studies of LAEs have been completed using narrow-band filter searches probing a small redshift range, and thus a small volume. We have developed a broad-band selection technique to probe the high equivalent width end of the LAE population. This method probes a much larger volume and redshift range. We have used CFHT-LS Deep 3 Field photometry to select LAE candidates for follow-up spectroscopy using WIYN/Hydra multi-object spectrograph. We have confirmed 30 strong LAEs in the CFHT-LS Deep 3 with line fluxes between 5e-17 and 8e-16 ergs/(cm² s), one QSO, and 2 low redshift H β -O[III] emitters out of 52 photometrically selected candidates. These LAE systems exhibit narrow emission lines and do not display He II or CIV emission at the depth of a 3- σ limit of ~1e-17 ergs/(cm² s Å) with 7 hours of exposure time on WIYN/Hydra.

430.25

The Assembly of the Red Sequence at z~1: Galaxy Transformation in High-Redshift Groups and Clusters

Brian Lemaux¹, L. M. Lubin¹, R. R. Gal², D. D. Kocevski³, C. D. Fassnacht¹, G. K. Squires⁴, J. Surace⁴, M. Lacy⁴

¹University of California, Davis, ²University of Hawai'i, ³University of California, Santa Cruz, ⁴California Institute of Technology.

Exhibit Hall

We present the color, spectral, and morphological properties of the 517 member galaxies of the Cl1604 supercluster at z~0.9. This system is a rich collection of five groups and three clusters that range in virial mass from 2x10^13 M_sun to 3x10^14 M_sun. The range of environments present in the supercluster,

varying from rich clusters dominated by a hot intracluster medium to sparse chains of galaxies dominated by starbursts and luminous AGN, make this system ideal to study galaxy evolution. Comparing the color and magnitude properties of the member galaxies of the eight constituent structures in the supercluster, we find that the three clusters as well as the combined group sample have well-established red sequences. Though the brightest red-sequence galaxies are found in the two most massive systems, many of the most massive early-type red-sequence galaxies are found, surprisingly, in the group environment. The red-sequence fraction is observed to strongly correlate with velocity dispersion, with the exception of our most massive system in which a large fraction of the member galaxies are blueward of the red-sequence. The blue galaxy population in our most massive system differs significantly from blue galaxy population observed in the groups as it is primarily comprised of low-mass late-type galaxies found at large clustocentric distances. The average spectral properties of the member galaxies of the three cluster systems is consistent with continuous starformation. In contrast, the average properties of the member galaxies of the group systems are much more diverse, with some groups comprised primarily of star-bursting or post-starburst galaxies, while other groups are primarily populated by continuous star-forming or quiescent galaxies. We also discuss the possible implications of these results in determining the processes responsible for transforming blue late-type galaxies to red, quiescent ellipticals in high redshift groups and clusters.

430.26

H-alpha And Multicolor Imaging Of LSB Galaxies

James Schombert¹, T. Maciel¹, S. McGaugh²

¹Univ. of Oregon, ²Univ. of Maryland.

Exhibit Hall

We present deep B, V and H-alpha imaging of 59 LSB galaxies selected from the PSS-II LSB catalog (Schombert et al. 1992). Combined with previous 21-cm observations, this sample represents one of the largest to date capable of studying the global and spatial star formation history of these unusual type of galaxies. The sample contains galaxies with central surface brightnesses ranging from 22 to 25 V mag arcsecs^-2 and sizes from 0.3 kpc to 10 kpc. The mean L(H-alpha) for the sample is 10^38 (ergs s^-1), which is a factor of 10 below previous work on irregular galaxies (i.e., Hunter & Elmgreen). We confirm a number of poorly defined relationships between color and surface brightness. The bluest regions are the highest in surface brightness (recent areas of star formation), although never above the

central surface brightnesses of the galaxy as is typical in normal spirals. While the brightest regions have B-V colors between 0.1 and 0.4, even the faintest regions have mean colors 0.4 and 0.6, in contradiction with their extremely low stellar densities.

Central surface brightness is crudely correlated with H-alpha emission (total current star formation rate). However, HII regions are small, and uncorrelated with stellar density on a local scale (i.e. visual appearance is no predictor of H-alpha emission).

Numerous color feature are seen in the sample ranging from typical color gradients to linear features indicative coherent star formation events. We also report the discovery of "blue bubbles", circular regions of blue color centered on H-alpha knots.

430.27

The Impact Of Secular Features On The Evolution Of Disk Galaxies.

Preethi Nair¹, COSMOS/zCOSMOS group

¹INAF - Astronomical Observatory of BOLOGNA, Italy.

Exhibit Hall

The role of bars in driving secular evolution of galaxies is still highly debated. Studies on the fraction of barred galaxies in the local universe and high redshift, and their role in building bulges and triggering

AGN have not yielded consistent results. Recently, using a sample of ~14,000 SDSS galaxies with detailed visual classifications including bars and rings, I was able to reconcile the disparity in the reported optical bar fractions. In this work, I extend the analysis to high-redshift, using a sample of ~20,000 equally detailed visual classifications from the zCOSMOS survey. In addition, I will present results on the impact of bars on the metallicity evolution of galaxies and their correlations with AGN activity.

430.28

Most Submillimeter Galaxies are Major Mergers

Engel Hauke¹, L. J. Tacconi¹, R. I. Davies¹, R. Neri², I. Smail³, S. C. Chapman⁴, R. Genzel¹, P. Cox², T. R. Greve⁵, R. J. Ivison⁶, A. Blain⁷, F. Bertoldi⁸, A. Omont⁹

¹MPE, Germany, ²IRAM, France, ³Durham University, United Kingdom, ⁴IoA, United Kingdom, ⁵University of Copenhagen, Denmark, ⁶University of Edinburgh, United Kingdom, ⁷California Institute of Technology, ⁸Argelander-Institut, Germany, ⁹CNRS, France.

Exhibit Hall

We analyse subarcsecond resolution interferometric CO line data for twelve sub-millimetre-luminous (S850um > 5mJy) galaxies with redshifts between 1 and 3, presenting new data for four of them. Morphologically and kinematically most of the twelve systems appear to be major mergers. Five of them are well-resolved binary systems, and seven are compact or poorly resolved. Of the four binary systems

for which mass measurements for both separate components can be made, all have mass ratios of 1:3 or closer.

Furthermore, comparison of the ratio of compact to binary systems with that observed in local ULIRGs indicates that

at least a significant fraction of the compact SMGs must also be late-stage mergers.

In addition, the dynamical and gas masses we derive are most consistent with the lower end of the range of stellar masses published for these

systems, favouring cosmological models in which SMGs result from mergers.

These results all point to the same conclusion, that likely most of the bright SMGs with $L_IR > 5x10^{12}$ L_sun are major mergers.

430.29

The Evolution of the Far-Infrared Luminosity Function in the Spitzer Wide-area Infrared Extragalactic Legacy Survey

Harsit Patel¹, D. L. Clements¹, M. Rowan-Robinson¹, M. Vaccari²

¹Imperial College London, United Kingdom, ²University of Padova, Italy.

Exhibit Hall

We construct the rest-frame luminosity functions (LFs) at 70 and 160 μ m using data from the Spitzer Wide-area Infrared Extragalactic (SWIRE) survey in the XMMLSS and Lockman-Hole fields. The 70 μ m LF constructed over the redshift range 0 < z < 1 shows strong positive evolution and can be demonstrated as being pure luminosity evolution (modelled as L*(z) \propto (1+z)^P) with P = 3.57±0.1. Modelling the 70 μ m LF with luminosity and density evolution model (modelled as $\phi^* \propto (1+z)^Q$) gave P = 3.51± 0.35 and Q = 0.13±0.7. The 160 μ m LF was computed in the redshift range 0 < z < 0.6 and modelled with the pure luminosity evolution with P = 2.36±0.2. We use the 70 μ m LF to derive the infrared (IR) energy density and star formation rate (SFR) and modelling it as $\propto (1+z)^{\gamma}$ gave $\gamma = 4.1\pm0.1$. We find that luminous and ultraluminous infrared galaxies (LIRGs and ULIRGs) contribute $\sim 20\pm5\%$ to the total IR luminosity density at z \sim 0 and increases to $\sim 65\pm10\%$ by z = 1, which shows that at z ~ 1 most of the star formation is produced by LIRGs and ULIRGs. Our results are in agreement with similar studies carried out with Spitzer at 24 μ m. I thank the Science and Technology Funding Council (STFC) for the financial support.

430.30 Optical Morphology of Faint Radio Sources in the GOODS-N Field Thomas ${\rm Connor}^1$

¹Case Western Reserve University.

Exhibit Hall

Radio emission from faint radio populations (sub-mJy) is powered by star formation and low luminosity AGN. Distinguishing between the two, however, relies on several inexact methods. One such method, the FIR-radio correlation, locates star formation powered radio sources, but is contaminated by sources classified as AGN by their optical SEDs. Especially for sources without available spectroscopy, conclusions based on the broad-band optical/NIR SED may be affected by high levels of dust attenuation around sites of high star formation. Even for objects with available IR photometry, where the FIR-radio correlation may be used to identify star-formation powered radio sources, there have been claims that it might be contaminated by low-luminosity AGNs. By looking into a faint radio source population and combining a multi-wavelength catalog with optical morphology, we were able to investigate the nature of faint radio sources by including the analysis of their structural properties and high resolution color images. In particular, probing the population of red sequence objects revealed many sources of late-type morphology. While some of these may be quiescent disk galaxies, it seems likely that a significant fraction of the red sequence of the radio selected sample is made of reddened star-forming sources.

430.31

The Stellar Content of Fossil Galaxies

Craig Harrison¹, C. Miller¹, XCS Collaboration

¹University of Michigan.

Exhibit Hall

The true nature of fossil galaxies is yet to be determined. Originally thought to represent the end-product of merging in galaxy groups, and thereby a special class of objects, recent work has found few differences when compared with field ellipticals. With this poster we present a sample of 30 fossil galaxies (found within the XCS and the SDSS) and the results of a study of their stellar populations and star-formation histories. Our results suggest that fossil

galaxies are more massive, older and more metal-rich than isolated galaxies and are marginally so when compared with BCGs.

430.32

Keck Spectroscopy Of Lyman-break Galaxies And Its Implications For The Uv-continuum And Ly α Luminosity Functions At Z > 6

Linhua Jiang¹, E. Egami¹

¹University of Arizona.

Exhibit Hall

We present Keck spectroscopic observations of z>6 Lyman-break galaxy (LBG) candidates in the Subaru Deep Field (SDF). The candidates were selected as i'-dropout objects down to z'=27 AB magnitudes from an ultra-deep SDF z'-band image. With the Keck spectroscopy we identified 19 LBGs with prominent Lya emission lines at 6<z<6.4. The median value of the Lya rest-frame equivalent widths (EWs) is 50 A, with four EWs greater than 100 A. This well-defined spectroscopic sample spans a UV-continuum luminosity range of -21.8 < M < -19.5, or 0.6 - 5 L*(UV), and a Lya luminosity range of 0.3-3 x 10^{43} erg/s, or 0.3-3 L*(Lya). We derive the UV and Lya luminosity functions (LFs) from our

sample at z=6.2 after we correct for sample incompleteness. We find that our measurement of the UV LF is consistent with the results of previous studies based on photometric LBG samples at 5<z<7. Our Lya LF is also generally in agreement with the results of Lya-emitter surveys at z=5.7 and 6.6. This study shows that deep spectroscopic observations of LBGs can provide unique constraints on both the UV and Lya LFs at z>6.

430.33

AKARI Observation of North Ecliptic Pole Supercluster at z=0.087

Jongwan Ko¹, M. Im², H. Lee², M. Lee², Y. Jeon², S. Kim², H. Shim³, and LSNEP team ¹Yonsei University Observatory, Korea, Republic of, ²Seoul National University, Korea, Republic of, ³Spitzer Science Center.

Exhibit Hall

We present the mid-infrared (mid-IR) properties and environments of red-sequence galaxies within a supercluster in North Ecliptic Pole (NEP) area at redshift ~0.087, using AKARI NEP-Wide (5.8 deg²) IR imaging survey in conjunction with ultraviolet–near-IR spectral energy distributions (SEDs). The supercluster sample is based on our follow-up optical spectroscopy within 0.07 < z < 0.10, and is limited to galaxies with $M_* > 10^{9.5} M_{[solar]}$. We present mid-IR SEDs of red-sequence galaxies thanks to the continuous coverage in mid-IR (7–18 μ m) of the AKARI. Most importantly, such mid-IR flux allows us to trace not only star formation rate (SFR), but also the presence of intermediate age populations showing excess emission over the stellar light in mid-IR. As such, we find that the red-sequence samples do not only contain passively evolving red early-type galaxies, but also contaminated with: 1) disk-dominated star-forming galaxies which have SFRs per unit stellar mass lower than blue-cloud galaxies, and 2) early-type galaxies showing broad non-stellar emission in mid-IR compared to normal red early-type galaxies. Those two populations may represent transition objects between blue spiral galaxies and red early-type galaxies. We present how those two transition galaxies depend on their local density and stellar mass, and discuss which factor is the primary predictor of star formation activity and the morphological transformation.

430.34

Bayesian Inference of Galaxy Morphology

Ilsang Yoon¹, M. Weinberg¹, N. Katz¹

¹University of Massachusetts Amherst.

Exhibit Hall

Reliable inference on galaxy morphology from quantitative analysis of ensemble galaxy images is challenging but essential ingredient in studying galaxy formation and evolution, utilizing current and forthcoming large scale surveys. To put galaxy image decomposition problem in broader context of statistical inference problem and derive a rigorous statistical confidence levels of the inference, I developed a novel galaxy image decomposition tool, GALPHAT (GALaxy PHotometric ATtributes) that exploits recent developments in Bayesian computation to provide full posterior probability distributions and reliable confidence intervals for all parameters. I will highlight the significant improvements in galaxy image decomposition using GALPHAT, over the conventional model fitting algorithms and introduce the GALPHAT potential to infer the statistical distribution of galaxy morphological structures, using ensemble posteriors of galaxy morphological parameters from the entire galaxy population that one studies.

The Evolution Of Size And Stellar Mass Of Passively Evolving Galaxies From Redshift Z~2 To The Present

Paolo Cassata¹, M. Giavalisco¹, Y. Guo¹, S. Salimbeni¹

¹University of Massachusetts.

Exhibit Hall

We study the evolution of the number density and size of passive early-type galaxies from z^2 to z^0 , exploiting the unique dataset available in the GOODS fields. In particular, we select a robust sample of ~800 massive (M>10^10M_sun) and passive (SSFR<10^-2 Gyr^-1) galaxies at 1<z1 and z<1 the morphological K-correction for passive galaxies is small, with sizes basically unchanged, within the errors, from UV to optical rest-frame. Moreover, independently on the rest-frame, we measure a significant evolution in the mass-size relation from from z^2 to z^1 and from z^1 to z^0 , indicating that the size growth of passive galaxies is still ongoing even at z<1. However, even though the number density of all passive early-type galaxies increases by a factor of 10 from z^2 to z^1 , and by another factor of 2 from z^1 to z^0 , the number density of compact galaxies basically remain unchanged from z^2 to z^0 . This implies that either: 1. the compact galaxies at z^2 gradually move onto the local relation, while new compact galaxies are formed at z<2 and are responsible for the number evolution; or 2. the compact galaxies that we see at z^2 evolve passively to z^0 while new larger early-types are assembled at z<2, being responsible for the huge number density evolution.

430.36

Improved And Quality Assessed Emission And Absorption Line Measurements In Sloan Digital Sky Survey Galaxies

Kyuseok Oh¹, M. Sarzi², K. Schawinski³, S. K. Yi¹

¹Yonsei University, Korea, Republic of, ²University of Hertfordshire, United Kingdom, ³Yale University. Exhibit Hall

We have established a new database of absorption and emission line measurements from the Sloan Digital Sky Survey 7th data release for the galaxies within a redshift of 0.2. This work used publicly available codes, pPXF(penalized pixel-fitting) and GANDALF(gas and absorption line fitting), to achieve robust spectral fits and reliable measurements. The absorption line strengths measured by SDSS pipeline are seriously contaminated by emission fill-in. We effectively separate emission lines from absorption lines. For instance, this work successfully extract [NI] doublet from Mgb and it leads to more realistic result of alpha enhancement on late-type galaxies compared to the previous database. Besides accurately measuring line strengths, the database will be provided with new parameters that are indicative of line strength measurement quality. Users can build a subset of database optimal for their studies using specific cuts in the fitting quality parameters as well as empirical signal-to-noise. Applying these parameters, we found galaxies with dramatically broad line regions among the galaxies with poor fitting quality parameters. We applied a new continuum finding prescriptions to newly identified BLRs and they turned out to be Seyfert I nuclei.

430.37

IGM Overdensities towards Galaxies at High-Redshift

Brenda L. Frye¹, M. Hurley², D. Bowen³, D. Coe⁴, X. Fan⁵, T. Tripp⁶, B. Holden⁷, E. Egami⁵, Y. Matsuda⁸ ¹University of San Francisco, ²Dublin City University, Ireland, ³Princeton University, ⁴STScl, ⁵University of Arizona, ⁶University of Massachusetts, ⁷University of California, ⁸Durham University, United Kingdom. Exhibit Hall

We present a high signal-to-noise spectrum of a bright galaxy at z = 4.9 in 14 h of integration on VLT FORS2. This galaxy is extremely bright, i_850 = 23.10 +/- 0.01, and is strongly-lensed by the foreground

massive galaxy cluster Abell 1689 (z=0.18). Stellar continuum is seen longward of the Ly-alpha emission line at ~7100 A, while intergalactic H I produces strong absorption shortward of Ly-alpha. Two transmission spikes at ~6800 A and ~7040 A are also visible, along with other structures at shorter wavelengths. Although fainter than a QSO, the absence of a strong central ultraviolet flux source in this star forming galaxy enables a measurement of the H I flux transmission in the intergalactic medium (IGM) in the vicinity of a high redshift object. We find that the effective H I optical depth of the IGM is remarkably high within a large 14 Mpc (physical) region surrounding the galaxy compared to that seen towards QSOs at similar redshifts. Evidently, this high-redshift galaxy is located in a region of space where the amount of H I is much larger than that seen at similar epochs in the diffuse IGM. We argue that observations of high-redshift galaxies like this one provide unique insights on the nascent stages of baryonic large-scale structures that evolve into the filamentary cosmic web of galaxies and clusters of galaxies observed in the present universe. Follow-up narrow-band imaging at Subaru Observatory has revealed an a coincident overdensity of Ly-alpha Emitters.

430.38

The Herschel View of Brightest Cluster Galaxies

Tim Rawle¹, E. Egami¹, A. Edge², M. Rex¹, Herschel Lensing Survey, LoCuSS ¹University of Arizona, ²Durham University, United Kingdom. Exhibit Hall

In central regions of rich galaxy clusters, the intracluster medium can be sufficiently dense that cooling to stellar temperatures occurs on timescales shorter than the cluster lifetime. Clusters can thus be crudely categorized by the presence of this "cool-core", often identified by X-ray-derived mass deposition rates or central H-alpha emission. However, observed cooling is slower than expected, indicating an additional injection of energy. We present infrared analysis of BCGs in a sample of 60 intermediate-redshift clusters, concentrating on Herschel Space Observatory far-infrared (100-500um) photometry from the Herschel Lensing Survey (HLS) and Local Cluster Substructure Survey (LoCuSS). The sample includes known cool-core clusters, but crucially also non-cool-core clusters, allowing a homogeneous investigation of both populations. At these redshifts, Herschel data straddles the peak of the dust emission component, enabling a direct measure of the far-infrared luminosity and hence constraints on star formation rate. We find that 10 BCGs have star formation detected by Herschel, showing that cooling is not entirely suppressed, and total infrared luminosity appears correlated with cool-core indicators. Indeed, all far-infrared luminous BCGs reside within cool-core clusters, strongly suggesting that the detectable dust is associated with the cold gas component rather than the underlying stellar population.

430.39

The SDSS DR6 Adaptive Match Filter Cluster Catalog And the Brightest Cluster Galaxies

Elena Pierpaoli¹, T. Szabo¹, A. Pipino¹, F. Dong², J. Gunn²

¹University of Southern California, ²Princeton University.

Exhibit Hall

We present a new cluster catalog extracted from SDSS-DR6 using an adaptive matched filter (AMF) cluster finder. We identify 69,173 galaxy clusters in the redshift range 0.045<z<0.78.

We compare the AMF catalog with the maxBCG, GMBCG and Wen et al ones.

A comparison with the maxBCG catalog shows that clusters match at about the 40% level for all redshifts. The AMF catalog matches all maxBCG clusters with 100<Ngal and the maxBCG one about 90% of AMF clusters with 100<Lambda200. For the catalog produced by Wen, Han, and Liu from SDSS DR6 data, we find matches for about 25% of their clusters.

We find 539 matches with X-ray clusters, 119 with temperature measurements.

We present scaling relations between optical and X-ray properties and cluster center comparison. Finally, we study the properties of the Brightest Cluster Galaxies (BCGs).

We find that the BCG luminosity distribution is close to a Gaussian, whose mean has a redshift evolution broadly consistent with pure aging of the galaxies. Richer clusters tend to have brighter BCGs, however less dominant than in poorer systems. 4-9% of our BCGs are at least 0.3 mag bluer in the g-r colour than the red-sequence at their given redshift. Such a fraction decreases to 1-6% for clusters above a richness of 50, where 3% of the BCGs are 0.5 mag below the red-sequence. In terms of redshift evolution, the overall blue fraction seems to increase with redshift from 5% at 0.1<z<0.2 to 10% at 0.2<z<0.3. We also cross-matched our catalog with UV data from Galex. We show a correlation between offset from the optical red-sequence and the amount of UV-excess.

We cross-matched our catalog with the ACCEPT cluster sample, and find that blue BCGs tend to be in clusters with low entropy and short cooling times.

Research supported by NASA and NSF.

430.40

Towards Measuring Black Hole Spin from Signatures in the Complex Visibility Daniel J. D'Orazio $^{\rm 1}$

¹Columbia University.

Exhibit Hall

A new approach to estimating black hole spin from interferometric accretion disc data is brought forth. We observe that unique estimates for black hole spin can be discerned from the imaginary components of the complex visibility function. This is due to the link between asymmetries induced in the disk brightness profile by spin and the ability of the imaginary component of the visibility to probe asymmetry in the brightness profile.

430.41

A Sample Of Sagittarius Debris From The Parallel Stripes Of SDSS

Zhu Ling¹, M. Smith²

¹*Tsinghua University,* ²*KIAA at Peking university, China.*

Exhibit Hall

The SDSS equatorial stripe (stripe 82) and the parallel stripes (stripe 86 and 79) contain spectroscopic data for over tens of thousand stars in total. We have identified and analysed Sagittarius debris through the radial velocity of the stars. The stars in the stream have a global radial velocity different from the stars in the halo, and they also have their own velocity dispersion. This dispersion gives an important constraint on simulations of the Sagittarius stream, which can determine the mass of the progenitor and also diagnose the gravitational potential of the Milky Way. Combined with photometry, a blue horizontal star and blue stragglers sample of Sagittarius debris stars have been obtained. The samples are thought to be clean, which means the contamination from the smooth halo is constrained to be very low. Using the wide variety of information available for these stars (metallicity, radial velocity, gravity, photometry), we are able to gain deep insights into the nature of the Sagittarius system. There is probably another stream intersect sagittarius stream at this area. This new stream has different radial velocity than sagittarius in the position of stripe 82. This stream can also be detected in the BHB sample from stripe 86 and 79. It is most likely to be the Cetus Polar Stream recently reported.

431 *Education and Outreach* Poster Session *Exhibit Hall*

431.01

Nurturing The STEM Pipeline: Graduate Student Leadership In NIRCam's Ongoing E/PO Mission For JWST

Wayne M. Schlingman¹, N. Stock¹, J. Teske¹, K. Tyler¹, B. Biller², J. Donley³, A. Hedden⁴, K. Knierman⁵, P. Young⁵

¹The University of Arizona, ²Max-Planck-Institut fuer Astronomie, Germany, ³Space Telescope Science Institute, ⁴Center for Astrophysics, ⁵Arizona State University.

Exhibit Hall

The Astronomy Camp for Girl Scout Leaders is an education and public outreach (E/PO) program offered by the science team of the Near-InfraRed Camera (NIRCam) for NASA's 6.5-meter James Webb Space Telescope (JWST). Since 2003, astronomy graduate students have helped design and lead biannual "Train the Trainer" workshops for adults from the Girl Scouts of the USA (GSUSA), engaging these trainers in the process of scientific inquiry and equipping them to host astronomy-related activities at the troop level. These workshops have helped revise the national GSUSA badge curriculum and directly benefitted thousands of young girls of all ages, not only in general science and math education but also in specific astronomical and technological concepts relating to JWST. To date, nine graduate students have become members of NIRCam's E/PO team. They have developed curriculum and activities used to teach concepts in stellar nucleosynthesis, lookback time, galaxy classification, etc. They have also contributed to the overall strategic approach and helped lead more general activities in basic astronomy (night sky, phases of the Moon, the scale of the Solar System and beyond, stars, galaxies, telescopes, etc.) as well as JWST-specific research areas in extrasolar planetary systems and cosmology, to pave the way for girls and women to understand the first images from JWST. The resulting experience has empowered these students to propose and to develop their own E/PO programs after graduation as postdocs and young faculty. They also continue as part of NIRCam's growing worldwide network of 160 trainers teaching young women essential STEM-related concepts using astronomy, the night sky environment, applied math, engineering, and critical thinking. NIRCam and its E/PO program are funded by NASA under contract NAS5-02105.

431.02

"Far Horizons" -- Near-space Exploration At The Adler Planetarium

Mark Hammergren¹, G. Gyuk¹, R. B. Friedman¹

¹Adler Planetarium.

Exhibit Hall

Over the past four years, the Adler Planetarium has developed a diverse suite of educational activities involving hands-on scientific exploration via our "Far Horizons" high-altitude ballooning program. These efforts largely have been focused on increasing excitement and motivation for learning outside of school time, and include middle school summer camps, a high school summer program (the Astro-Science Workshop), school-year internships for high school students, summer internships for undergraduates, a NSF-funded graduate fellowship, and an active public volunteer program. In 2010, our programs were dedicated to the memory of renowned Chicago adventurer and explorer Steve Fossett. In 2011, in continued tribute to Steve Fossett, we further expand our out-of-school time programs with a summer workshop designed to enable high school teachers to form and advise student high-altitude ballooning clubs. This model program will be developed as one element of our ongoing partnership with the Air

Force Academy High School in Chicago.

This material is based in part upon work supported by the National Science Foundation under Grant No. 0525995.

431.03

Astrophysics Science Division Education and Public Outreach at NASA's Goddard Space Flight Center Faith Tucker $^{\rm 1}$

¹Whitman College.

Exhibit Hall

Whether by participating in an after-school program or perusing a blog, discovering the marvels of the universe can inspire a love of astronomy, and science in general, in students and adults alike. The Astrophysics Science Division's (ASD) Education and Public Outreach (EPO) team at NASA's Goddard Space Flight develops programs and curricula to engage students, educators and the general public in the exciting research being done at Goddard and to foster a better understanding of the universe in general. The ASD EPO team provides formal, informal and outreach materials and programming covering all aspects of astrophysics, including topics such as stellar evolution, galaxies, black holes, supernovae, telescopes and spectroscopy. The programs are designed to engage students in hands-on learning activities and to formulate content in such a way that it is relevant to the audience. These programs are essential to enhance the public's understanding of astronomy, to inspire young minds and garner public support for astronomy research.

431.04

RSpec: New Real-time Spectroscopy Software Enhances High School and College Learning Tom ${\rm Field}^1$

¹*Field Tested Software.*

Exhibit Hall

Nothing beats hands-on experience!

Students often have a more profound learning experience in a hands-on laboratory than in a classroom. However, development of inquiry-based curricula for teaching spectroscopy has been thwarted by the absence of affordable equipment.

There is now a software program that brings the excitement of real-time spectroscopy into the lab. It eliminates the processing delays that accompany conventional after-the-fact data analysis -- delays that often result in sagging enthusiasm and loss of interest in young, active minds.

RSpec is the ideal software for high school or undergraduate physics classes. It is a state-of-the-art, multi-threaded software program that allows students to observe spectral profile graphs and their colorful synthesized spectra in real-time video. Using an off-the-shelf webcam, DSLR, cooled-CCD or even a cell phone camera, students can now gain hands-on experience in gathering, calibrating, and identifying spectra. Light sources can include the sun, bright night-time astronomical objects, or gas tubes. Students can even build their own spectroscopes using inexpensive diffraction "rainbow" glasses. For more advanced students, the addition of an inexpensive slitless diffraction grating allows the study of even more exciting objects. With a modest 8" telescope, students can use a simple webcam to classify star types, and to detect such exciting phenomena as Neptune's methane-absorption lines, M42's emission lines, and even, believe it or not, the redshift of 3C 273. These adventures are possible even under light-polluted urban skies. RSpec is also an excellent program for amateur astronomers who want to transition from visual CCD imaging to actual scientific data collection and analysis.

As the developer of this software, I worked with both teachers and experienced spectroscopists to ensure that it would bring a compelling experience to your students. The response to real-time, colorful data has been very enthusiastic both in the classroom and in public outreach.

The Black Holes Traveling Exhibition: Visitors Go In, But Does Learning Come Out?

Mary E. Dussault¹, R. Gould¹, S. Sunbury¹, R. Londhe²

¹Harvard-Smithsonian, CfA, ²Goodman Research Group.

Exhibit Hall

How do you make a fascinating but challenging scientific topic accessible to the broadest audience of museum-goers? What kinds of learning outcomes might escape from a visit to an exhibition on black holes? In 2009, the Harvard-Smithsonian Center for Astrophysics developed a 2500 square foot interactive museum exhibition with funding from the National Science Foundation and NASA. The project pursued two innovations to achieve its educational goals: 1) the participation of youth teams as co-developers of several exhibit and program components; and 2) the use of networked exhibit technology to personalize the visitor experience, to support learning over time including beyond the gallery, and to provide a rich quantitative source of embedded evaluation data. Visitor use a bar-coded "Black Holes Explorer's Card" to gather digital data as they navigate the exhibition, and an automated web-content authorizing system creates a personalized online journal of their experience that they can access once they get home. Summative evaluation results reported by Goodman Research Group include successful implementation of the two project innovations, and multiple positive visitor outcomes in knowledge, engagement and attitudes towards science. Furthermore, the evidence shows that use of the bar-coded Explorer's Card significantly enhances these positive outcomes and that the youth-designed elements contributed to visitor engagement.

431.06

What Lies Behind NSF Astronomer Demographics? Subjectivities of Women, Minorities and Foreignborn Astronomers within Meshworks of Big Science Astronomy

Reynal Guillen¹, D. Gu², J. Holbrook³, L. F. Murillo², S. Traweek²

¹UCLA - NSF, ²UCLA, ³University of Arizona.

Exhibit Hall

Our current research focuses on the trajectory of scientists working with large-scale databases in astronomy, following them as they strategically build their careers, digital infrastructures, and make their epistemological commitments. We look specifically at how gender, ethnicity, nationality intersect in the process of subject formation in astronomy, as well as in the process of enrolling partners for the construction of instruments, design and implementation of large-scale databases. Work once figured as merely technical support, such assembling data catalogs, or as graphic design, generating pleasing images for public support, has been repositioned at the core of the field. Some have argued that such databases enable a new kind of scientific inquiry based on data exploration, such as the "fourth paradigm" or "data-driven" science.

Our preliminary findings based on oral history interviews and ethnography provide insights into meshworks of women, African-American, "Hispanic," Asian-American and foreign-born astronomers. Our preliminary data suggest African-American men are more successful in sustaining astronomy careers than Chicano and Asian-American men. A distinctive theme in our data is the glocal character of meshworks available to and created by foreign-born women astronomers working at US facilities. Other data show that the proportion of Asian to Asian American and foreign-born Latina/o to Chicana/o astronomers is approximately equal. Futhermore, Asians and Latinas/os are represented in significantly greater numbers than Asian Americans and Chicanas/os. Among professional astronomers in the US, each ethnic minority group is numbered on the order of tens, not hundreds.

Project support is provided by the NSF EAGER program to University of California, Los Angeles under award 0956589.

431.07 The NASA Lunar Science Institute Education and Public Outreach Program Doris \mbox{Daou}^1

¹NASA Lunar Science Institute.

Exhibit Hall

The National Aeronautics and Space Administration (NASA) has a clear set of goals and objectives related to education and public outreach.

The NASA lunar Science Institute (NLSI) has adopted these goals as a backbone of our education program and made Education and Outreach major pillars in its foundation and Mission Statements. In this talk we will look at how the NLSI Education and Public Outreach (EPO) program is becoming a strong resource in preparing the next generation of Lunar scientists and in sharing with the public the excitement of discoveries we make when we explore the Moon.

432

High Energy, Cosmology and Other Topics Poster Session *Exhibit Hall*

432.01

The Clustering of 12 and 22 micron Star Forming Galaxies from WISE/SDSS Surveys Emilio Donoso¹, L. Yan¹

¹Caltech.

Exhibit Hall

The Wide-Field Infrared Survey Explorer (WISE) satellite has surveyed the entire sky at 12 and 22 microns down to a flux limit of 1 and 6 mJy, respectively. By cross-matching this data with the SDSS, we derive a large sample of star forming galaxies. Herein, we present a comprehensive study of the clustering of these sources via the projected cross-correlation function, w(rp), and matched control samples. This allows us to trace the clustering relative bias of the population as function of the star formation rate, and characterize in detail the typical environments of star forming galaxies in the local universe.

432.02

Tomography Of The UV Outflow In IRAS F22456-5125 Using High S/N HST COS Observations

Benoit Borguet¹, D. Edmonds¹, N. Arav¹, J. Dunn²

¹Virginia Tech, ²Augusta State University.

Exhibit Hall

In recent years AGN outflows have gained strong interest as a main agent in AGN feedback scenarios. Determining the mass flux and kinetic luminosity from these outflows requires an accurate determination of the column densities as well as a distance estimate to the outflow. Using the brand new UV COS spectrograph on board of the HST, we obtained high S/N spectrum of IRAS F22456-5125 allowing us to derive the physical conditions as well as accurate distance determination for several components of the UV outflow.

We acknowledge the NSF for funding this research project.

The Galactic Scale UV Outflow Discovered In High S/N HST COS Observations Of IRAS F04250-5718 Doug Edmonds¹, B. Borguet¹, N. Arav¹, S. Penton², J. Dunn³

¹Virginia Tech, ²University of Colorado, ³Augusta State University.

Exhibit Hall

We report on the discovery of a large scale AGN outflow in IRAS F04250-5718. Analysis of absorption troughs in high S/N data from HST COS observations made in June of 2010 reveals an outflow ~50 kpc from the central source. The outflow is unusual in both its extremely large distance and its photoionization structure. While multiple ionization components are necessary to fit data in X-ray absorption studies, a single ionization parameter normally suffices for UV studies. In this outflow, however, we require at least two ionization parameters to fit the UV data.

432.05

New Results on Testing General Relativity From the Latest Combined Cosmological Data Sets Jason Dossett¹, J. Moldenhauer¹, M. Ishak¹

¹*The University of Texas at Dallas.*

Exhibit Hall

Recently, much attention has gone into detecting deviations from general relativity in the growth history of the universe by parameterizing both modifications to Poisson's equation, as well as the ratio between the two metric potentials in the perturbed FLRW metric. We compare some of the various parameterizations that that have been proposed in recent literature. Using current cosmological data including Type Ia supernovae data from the Supernova Cosmology Project's Union 2 compilation, baryon acoustic oscillations, CMB temperature and polarization spectra from WMAP 7, the SDSS DR7 matter power spectrum, Integrated Sachs Wolfe-galaxy cross-correlations with galaxies from the 2MASS and SDSS LRG surveys, and the latest HST COSMOS 3D weak lensing tomography, we place constraints on some of these parameters. Indeed, detecting a deviation from general relativity using these parameterizations would shed light on the question of whether the observed cosmic-acceleration is due to an as of yet unknown dark energy permeating the universe or a modification of general relativity are consistent with all current data. Of course, this may change with future, higher precision data.

432.06

The Precision Array for Probing the Epoch of Reionization

Jonathan Pober¹, A. Parsons¹, D. Backer¹, R. Bradley², C. Parashare², N. Gugliucci², E. Benoit³, J. Aguirre⁴, D. Jacobs⁴, D. Moore⁴, C. Carilli³, J. Manley⁵, C. van der Meere⁵

¹UC Berkeley, ²University of Virginia, ³NRAO, ⁴University of Pennsylvania, ⁵KAT, South Africa. Exhibit Hall

The Precision Array for Probing the Epoch of Reionization (PAPER) is an experiment to detect the heating and reionization of the IGM through the 21-cm line of neutral hydrogen. Due to cosmological redshifting, the emission from this epoch will be located in a band around 150 MHz. This poster will present our calibration work and recent observations of the low-frequency sky from our two 32 element PAPER arrays in Green Bank, WV and the Karoo, South Africa.

Contribution to the Diffuse Radio Background from Extragalactic Radio Sources

Tessa Vernstrom¹, D. Scott¹, J. V. Wall¹

¹University of British Columbia, Canada.

Exhibit Hall

How bright is the extragalactic radio sky - in other words the Cosmic Radio Background (or CRB)? This question can be answered in 2 ways: by making absolute measurements at different frequencies, (which is hard); or by adding up the contribution from individual sources (which is easy, but only gives lower limits). Here we use a compilation of radio counts to estimate the contribution of detected sources to the CRB in several different frequency bands. We apply a Monte Carlo Markov Chain technique to estimate the brightness values and uncertainties, paying attention to various sources of systematic error. We compare our results to absolute measurements from the ARCADE-2 experiment. If these measurements are correct and come from sources, then there must be an additional population of very faint radio galaxies, below where current data are probing. More specifically, the Euclidean-normalized counts at 1.4 GHz have to have an additional bump below about 10 micro-Jansky.

432.08

Vorticity in the Early Universe Adam Christopherson¹

¹Queen Mary, University of London, United Kingdom. Exhibit Hall

Vorticity is ubiquitous in nature however, to date, studies of vorticity in cosmology and in the early universe have been quite rare. In this work we use the technique of cosmological perturbation theory to investigate vorticity in the early universe. At first, or linear order, we reproduce the standard result that vorticity decays with the expansion of the universe. However, the higher order theory exhibits a qualitative difference from the linear order theory, namely that different types of perturbation (classified as scalar, vector or tensor) do not decouple. We show that at second order vorticity is sourced by a term quadratic in linear order energy density and entropy perturbations. This is a generalisation of previous work which focused on barotropic fluids, and is an extension of Crocco's theorem from classical fluid dynamics to a cosmological setting.

432.09

Hobby-Eberly Telescope Dark Energy Experiment Fiber Optic Testing System Lindsay Fuller $^{1}\,$

¹University of Texas at Austin.

Exhibit Hall

The Hobby-Eberly Telescope Dark Energy Experiment (HETDEX) is a spectroscopic survey that will collect data from nearly one million Lyman- α emitting galaxies at a redshift of 1.8 < z < 3.8 in order to characterize dark energy. To accomplish this, over 33,000 optical fibers will feed light from these galaxies into 150 Visible Integral-Field Replicable Unit Spectrographs (VIRUS), an order of magnitude greater than has been done before. A fiber optic test bench has been constructed at the University of Texas at Austin in order to test the transmission and focal ratio degradation (FRD) of individual fibers at several wavelengths ranging from 350-600nm. Furthermore, the fiber optic bundles are undergoing extensive lifetime tests at the Center for Electromechanics on the university's research campus which will simulate 10 years of motion on the Hobby-Eberly Telescope.

The Fermi Haze from Dark Matter Annihilations and Anisotropic Diffusion Gregory Dobler¹, I. Cholis², N. Weiner³

¹University of California, Santa Barbara, ²La Scuola Internazionale Superiore di Studi Avanzati, Italy, ³New York University.

Exhibit Hall

Recently we identified a large extended diffuse gamma-ray structure towards the Galactic center in full sky gamma-ray maps produced by the Fermi Gamma-Ray Space Telescope. This feature was dubbed the Fermi "haze" (Dobler et al. 2010) and more recently the Fermi "bubbles" (Su et al 2010). The Fermi haze is hard spectrum inverse Compton radiation from a population of energetic electrons that are too hard to be produced by typical astrophysical mechanisms, such as supernova shocks. While more exotic astrophysical scenarios may be plausible, here we explore the possibility that the hard spectrum electrons are due to dark matter annihlations in the Galactic halo and are propagated to the required volume by anisotropic diffusion effects. We develop a self-consistent anisotropic diffusion model and show that both the morphology and spectrum are well fit by the model. In addition, this model (which utilizes an XDM model for the dark matter particle with a self-annihilation cross section Sommerfeld enhancement of ~100) also produces the microwave synchrotron haze and locally observed cosmic-ray excesses by Fermi and PAMELA.

432.11

Toward an Enhanced BATSE Gamma-Ray Burst Catalog

Thomas J. Loredo¹, J. Hakkila², I. M. Wasserman¹

¹Cornell Univ., ²College of Charleston.

Exhibit Hall

The *Compton Gamma Ray Observatory* (CGRO) ceased operation and was de-orbited in 2000, passing the baton for twenty-first century gamma-ray burst (GRB) surveying from CGRO's Burst and Transient Source Experiment (BATSE) to *Swift*, and *Fermi*'s Gamma-ray Burst Monitor (GBM) (and a few smaller missions). But the *Swift* and *Fermi* instruments were not designed with the goals of producing a large, well-characterized GRB catalog, and they will detect far fewer GRBs during their lifetimes than BATSE did. The BATSE burst catalog will remain the key observational resource for addressing GRB population studies for a decade or more. Yet well under half of BATSE GRBs may be used for population studies, due to incomplete characterization of important aspects of the BATSE survey. We describe ongoing work aiming to characterize the full 5B BATSE GRB sample by calculating accurate exposure maps and efficiency functions for the sample. We describe the key elements of our calculations (including treatment of atmospheric scattering and statistical effects), and present new exposure maps for the 5B catalog. This work is supported by NASA's Astrophysics Data Analysis Program (ADP).

432.12

The Variable Quiescent X-Ray Emission of the Neutron Star Transient XTE J1701–462 Joel K. Fridriksson¹, J. Homan¹, R. Wijnands², E. M. Cackett³, N. Degenaar², M. Mendez⁴, D. Altamirano², E. F. Brown⁵, T. M. Belloni⁶, W. H. G. Lewin¹ ¹Massachusetts Institute of Technology, ²University of Amsterdam, Netherlands, ³University of Cambridge, United Kingdom, ⁴University of Groningen, Netherlands, ⁵Michigan State University, ⁶INAF-Osservatorio Astronomico di Brera, Italy.

Exhibit Hall

We have monitored the cooling of the neutron star in the transient low-mass X-ray binary XTE J1701–462 with Chandra and XMM-Newton since the source entered quiescence in 2007 after an exceptionally luminous 19-month outburst. A recent Chandra observation made almost 1200 days into quiescence indicates that the neutron star crust is likely still slowly cooling toward thermal equilibrium with the core. The current surface temperature is high compared to other quiescent neutron star transients, with an implied bolometric thermal flux of $^{5}\times 10^{33}$ erg/s. The overall cooling curve seems to have followed a broken power-law shape as predicted by theoretical models, although the observed break is considerably earlier than what is expected from theory. After rapid cooling during the first ~200 days of quiescence---strongly indicating a highly conductive neutron star crust---the source unexpectedly showed a large temporary increase in both thermal and non-thermal flux. Prompted by this we conducted a Swift monitoring program of the source during April–October 2010, with short observations taking place once every two weeks. During the program we detected short-term flares up to at least 1×10³⁵ erg/s, a factor of ~20 higher than the normal quiescent level. We compare this flaring---presumably arising from episodic low-level accretion---with the behavior observed from faint Galactic transients, and discuss whether flaring in XTE J1701–462 can significantly affect the cooling of the source and whether it can to some extent explain the high temperature of the neutron star core implied by our Chandra observations.

432.13

First Results from the QUIET Telescope Robert Dumoulin¹

¹Columbia University in The City of New York.

Exhibit Hall

The Q/U Imaging ExperimenT (QUIET), a ground-based experiment located in the Atacama Desert in Chile, measures the polarization of the Cosmic Microwave Background (CMB). In Phase I, it measures the CMB polarization at angular scales of 25 < I < 1000 using radiometer arrays in the Q (44 GHz) and W (95 GHz) frequency bands. In the period of October of 2008 to December of 2010, more than 7500 hours of CMB data were collected, first with the 19-element Q-band receiver and then with the 90-element W-band receiver. The Q- and W- band receivers each observed the same 4 low-foreground fields that covered ~1000 square degrees.

Here, we present the initial results of the Q-band receiver from Phase I, including the EE and BB power spectra in the multipole range 26 < I < 475, and our resulting tensor-to-scalar ratio r. Before examining the resulting power spectra, the data were studied with two independent analysis pipelines, each with its own large suite of null tests.

432.14

The Spin Of The Black Hole In The Soft X-ray Transient A0620-00

Lijun Gou¹, J. Mcclintock¹, J. Steiner¹, R. Narayan¹, A. Cantrell², C. Bailyn², J. Orosz³ ¹Harvard-Smithosian Center for Astrophysics, ²Department of Astronomy, Yale University, ³Department of Astronomy, San Diego State University.

Exhibit Hall

The Spin of the Black Hole in the Soft X-ray Transient A0620-00. A0620-00 is the prototype soft X-ray transient, which is an eruptive type of X-ray binary. We have recently determined accurate values for the black hole mass, orbital inclination angle, and distance. Building on these results, we measured the radius of the inner edge of the accretion disk around the black hole primary by fitting its thermal

continuum spectrum to our version of the relativistic Novikov-Thorne thin-disk model. We thereby estimated the spin parameter of the BH: $a/M = 0.12 \pm 0.19$, with a/M - 0.59 at the 3σ level of confidence. This result takes into account all sources of observational and model-parameter uncertainties. Despite the low spin, the intensity and properties of the radio counterpart, both in outburst and quiescence, attest to the presence of a strong jet. If jets are driven by BH spin, then current models indicate that jet power should be a steeply increasing function of spin. Consequently, the low spin of A0620-00 suggests that its jet may be disk driven.

432.15

Electromagnetic Emission from the Last Hours of Merging Supermassive Black Holes

Tanja Bode¹, T. Bogdanović², R. Haas¹, J. Healy¹, P. Laguna¹, D. Shoemaker¹

¹Georgia Institute of Technology, ²University of Maryland.

Exhibit Hall

Synergistic electromagnetic (EM) and gravitational wave (GW) observations from the coalescence of supermassive black holes (SBHs), considered to be the next observational frontier, will shed light on galaxy assembly and SBH growth. Computational modeling of the dynamics and accretion processes in this last evolutionary stage of SBH binaries is central to understanding the conditions under which EM emission accompanies GWs. On scales smaller than ~0.01 pc for a $10^7 M_{sun}$ binary, gravitational wave emission determines the orbital dynamics of SBH binaries and therefore EM emissions can only be studied within the context of fully relativistic simulations. We present results from fully general relativistic hydrodynamics simulations of the late inspiral and merger of SBH binaries within astrophysically relevant gaseous environments including circumbinary disks and hot, radiatively inefficient accretion flows. We find that the observability and characteristics of EM signatures are intricately connected to the physical properties of the binary and its environment. For instance, a sudden drop in EM luminosity will not only signal the merger of the SBHs but also the presence of hot, radiatively inefficient accretion flows, whereas dramatic changes in spectral emission lines close to the coalescence may signal the presence of a circumbinary disk.

432.16

On the Horizon Limits for Detection of Gravitational Waves from a Pulsar Kick Samuel Kai Grunblatt $^{\rm 1}$

¹Columbia University.

Exhibit Hall

Pulsar kicks are produced when a type Ia supernova occurs with a neutron star core remnant. The neutron star is then given a kick, a back-reaction of the supernova explosion. There are three main types of mechanisms which can produce this kick: a hydrodynamical mechanism, a magnetic-neutrino driven mechanism, and an electromagnetic mechanism. Based on estimates of pulsar birthrates in our galaxy, the horizon limit of detection for pulsar kicks has been found. Based on current models and estimates, the horizon limit for the detection of gravitational waves from a large pulsar kick may extend to nearby galaxies after the implementation of Advanced LIGO.

432.17

Classification of X-ray Sources in the XMM-Newton Serendipitous Source Catalog

Dacheng Lin¹, N. Webb¹, D. Barret¹, S. Farrell²

¹Centre d'Etude Spatiale des Rayonnements, France, ²University of Leicester, United Kingdom. Exhibit Hall

The Second XMM-Newton Serendipitous Source Catalog (2XMM) is the largest X-ray catalog ever produced, containing 262,902 unique sources. We study 4369 point sources from this catalog that have multiple pointings and have at least one detection with S/N>=20. For nearly one half of them we can

obtain source types from the literature. We find that different types of sources are associated with different regions in the X-ray color diagram, different inter-observation variability, and different X-ray-to-optical and X-ray-to-IR flux ratios. Based on this, we have derived optimal criteria to obtain classifications of the unknown sources.

432.18

Apsidal Motion of V578 Mon

Eugenio Garcia¹, L. Hebb², K. G. Stassun², A. Heiser³

¹Fisk- Vanderbilt Masters-PhD Bridge Program, ²Vanderbilt University, ³Vanderbilt Dyer Observatory. Exhibit Hall

We directly measure an apsidal period of 33.15 + -0.70 years for the double-lined eclipsing binary V578 Mon, a system of two B0.5 stars in star-forming region NGC 2244 within the Rosette Nebula. As a result of this apsidal period, measured accurately for the first time for this system, we report an updated eccentricity of 0.0778 +/- 0.0005, which differs significantly from the previously reported literature value of 0.0867+/- 0.0006. Also, we report preliminary absolute dimensions for V578 Mon, including masses, radii and temperatures. Finally, we provide a comparison of stellar evolution model predictions against our measurements for these massive stars; the final analysis will represent an important calibration of theoretical stellar evolution for high mass stars, which remain poorly calibrated by empirical measurements. Our analysis combines our own extensive multi-band photometry spanning nearly 40 years and photometry from the literature. Traditionally, apsidal motion of eccentric binary systems is calculated by measuring the effect of periastron advance on primary and secondary times of minima. Here we calculate the apsidal motion of V578 Mon using state-of-the-art eclipsing binary modeling software to take full advantage of our multi-year photometry, which covers multiple phases of the apsidal period, and which exhibits detailed ellipsoidal effects at all phases and epochs, providing a highly accurate measurement of the apsidal period and other stellar parameters.

432.20

WFIRST Exoplanet Science Joseph Catanzarite¹

¹JPL, California Institute of Technology.

Exhibit Hall

The Wide-Field Infrared Survey Telescope (WFIRST) is a NASA space observatory that will be capable of making a statistical census of extrasolar planets down to mass 0.1 Mearth, at star-planet separations beyond 0.5 AU, via planetary microlensing. By staring at a field in the galactic bulge, its wide-field infrared camera will detect planets orbiting foreground (lens) stars as they pass in front of more distant 'source' stars in the bulge. The foreground star-planet system magnifies the flux of the bulge star in time, and the mass and separation of the planet can be measured from the distinctive shape of the time-resolved light curve.

We determine the number of planets that WFIRST is expected to find, in logarithmic bins of planet mass from 0.1 Mearth to Mjupiter, as a function of the fraction of mission time devoted to a microlensing planet search. From these results, we determine how well the WFIRST exoplanet results can constrain a power-law planet mass distribution.

Massive Black Holes Lurking in Milky Way Satellites

Sandor Van Wassenhove¹, M. Volonteri¹, M. Walker², J. R. Gair² ¹University of Michigan, ²Institute of Astronomy, United Kingdom.

Exhibit Hall

As massive black holes (MBHs) grow from lower-mass seeds, it is natural to expect that a leftover population of progenitor MBHs should also exist in the present universe. Dwarf galaxies undergo a quiet merger history, and as a result, we expect that dwarfs observed in the local Universe retain some `memory' of the original seed mass distribution. Consequently, the properties of MBHs in nearby dwarf galaxies may provide clean indicators of the efficiency of MBH formation. In order to examine the properties of MBHs in dwarf galaxies, we evolve different MBH populations within a Milky Way halo from high-redshift to today. We dynamically evolve all halos merging with the central system, taking into consideration how the interaction modifies the satellites, stripping their outer mass layers. We compare the population of satellites to the results of N-body simulations and to the observed population of dwarf galaxies. We find good agreement for the velocity, radius and luminosity distributions. We compute different properties of the MBH population hosted in these satellites. We find that for the most part MBHs retain the original mass, thus providing a clear indication of what the properties of the seeds were. We derive the black hole occupation fraction (BHOF) of the satellite population at z=0.

432.22

The O-C Diagram of the Pulsating White Dwarf EC20058-5234 James Dalessio $^{\rm 1}$

¹University of Delaware.

Exhibit Hall

We present 13 years of timing measurements of the pulsating DB WD EC20058-5234. These measurements were taken in an attempt to measure the plasmon neutrino emission rate from this star. We find correlated sinusoidal variations in the O-Cs of the four highest amplitude modes. These variations are not due to a planetary companion. We present measurements of the plasmon neutrino emission rate and speculate as to the cause of the sinusoidal O-C variations.

432.23

The Benefits for Multi-Messenger Gravitational Wave Astronomy with a LIGO-Australia Detector Aidan F. Brooks¹, L. Wen¹, S. Whitcomb¹

¹Caltech.

Exhibit Hall

The last decade has seen first-generation interferometeric gravitational-wave (GW) detectors built, commissioned and operated at design sensitivity for extended periods. This has demonstrated the feasibility of such large-scale instruments. Second-generation GW detectors, designed to have 10x improvement in sensitivity yielding a 1000x fold increase in the volume of searchable space, are now under construction. Within the next decade we are expecting to witness two revolutionary developments in GW astronomy: (1) the first detections of gravitational waves, and (2) detection of the electromagnetic (EM) counterparts of gravitational-wave sources, e.g. gamma-ray bursts and supernovae. The information gathered from such combined GW-EM observations is expected to tell us much more about these extreme energy events than either observation by itself could hope to. Effective sky-localization of GW observations is essential for pairing such observations with EM counterparts. As with any basic triangulation, this is best served by a large and broad network of sensitive ground-based detectors. An exciting proposal to extend the 2nd generation GW network very much sooner than

anticipated has recently been raised. This proposal, to relocate one of the Advanced LIGO detectors from the US to Western Australia (LIGO-Australia), has such convincing scientific merit that it has progressed from conception to formal approval by the NSF (subject to certain conditions) in a little over 12 months. LIGO-Australia will add to the detector network the longest baseline, break the plane degeneracy of the detectors in the northern Hemisphere and therefore improve the network angular resolution dramatically. This poster will report on the status of this proposal and will discuss the scientific benefits of LIGO-Australia.

432.24

Wave Front Detection for the Virgo Gravitational Wave Detector Logan Richardson¹

¹University of Arizona.

. Exhibit Hall

The use of phase cameras in gravitational wave detectors allows imaging the spatial phase and amplitude distribution at the laser carrier and modulation sideband frequencies. Moreover, it allows mapping their dependence on the dynamics of the interferometer operating condition. The goal of this experiment is to build, test, and verify the performance of a new phase camera for the Advance Virgo gravitational wave detector. This report describes the background, the experimental set up, and the development of the data acquisition and signal processing for our phase camera.

This research was done on the part of a student international REU program, funded by the NSF, coordinated by the University of Florida and hosted at the NIKHEF institute.

432.25

The Different States of the Brightest Ultraluminous X-ray Source ESO 243-49 HLX-1

Mathieu Servillat¹, S. Farrell², D. Lin³, O. Godet³, D. Barret³, N. Webb³

¹Harvard-Smithsonian Center for Astrophysics, ²University of Leicester, United Kingdom, ³CESR, France. Exhibit Hall

The hyper luminous X-ray source ESO 243-49 HLX-1, which reaches a luminosity of 10^42 erg/s (0.2-10 keV), currently provides the strongest evidence for the existence of intermediate mass black holes. The value of the maximum X-ray luminosity is secured by the recent measurement of its distance (95 Mpc) through spectroscopic observations of its optical counterpart.

The ongoing monitoring campaign with Swift, which now covers one and a half year, has shown that HLX-1 seems to undergo spectral state transitions reminiscent of stellar mass black hole binaries, with large-scale flux variability by a factor of ~100 over timescales of weeks to months. Based on XMM-Newton and Chandra dedicated pointings, including triggered observations at low and high luminosity, we bring further evidence for spectral state changes between the high/soft and low/hard states. We also present a timing analysis of the available X-ray data, and compare the results with other ULXs, low mass active galactic nuclei and Galactic stellar mass black hole X-ray binaries.

432.26

Binary Evolution Leading to the Radio Pulsar PSR J1614-2230

Jinrong Lin¹, S. Rappaport¹, P. Podsiadlowski², L. Nelson³, B. Paxton⁴, P. Todorov⁵

¹*MIT,* ²*Oxford University, United Kingdom,* ³*Bishops University, Canada,* ⁴*University of California at Santa Barbara,* ⁵*Observatoire de Paris, France.*

Exhibit Hall

We have computed an extensive grid of binary evolution tracks to represent low- and intermediate mass X-ray binaries (LMXBs and IMXBs). The grid includes 42,000 models which covers 60 initial donor masses over the range of 1-4 solar masses and, for each of these, 700 initial orbital periods over the range of 10-250 hours. These results can be applied to understanding LMXBs and IMXBs that evolve analogously to

CVs; that form ultracompact binaries with orbital periods in the range of 6-50 minutes; and that lead to wide orbits with giant donors. We also investigate the relic binary recycled radio pulsars into which these systems evolve. To evolve the donor stars in this study, we utilized a newly developed stellar evolution code called "MESA" that was designed, among other things, to be able to handle very low-mass and degenerate donors. This first application of the results is aimed at an understanding of the newly discovered pulsar PSR J1614-2230 which has a 1.97 solar masses neutron star, orbital period = 8.7 days, and a companion star of 0.5 solar masses. We show that (i) this system is a cousin to the LMXB Cyg X-2, (ii) the initial donor star had a mass between 3.4-3.8 solar masses, (iii) neutron stars this massive are not easy to produce in spite of the initially high mass of the donor star, and (iv) the current companion star is largely composed of CO, but should have a surface H abundance of ~15%.

432.27

Followups to Gravitational-Wave Signal Candidates

Ryan Quitzow-James¹, LIGO Scientific Collaboration, Virgo Collaboration

¹University of Oregon.

Exhibit Hall

The LIGO and Virgo gravitational wave detectors have now completed joint data collection in their initial configurations. Phenomena searched for include the gravitational signatures of compact binary mergers, stellar core collapse, black hole creation, and other highly energetic astrophysical events. An important goal of this joint run was to search for EM counterparts to candidate gravitational wave events. Wide-field optical telescopes and Swift were enlisted to promptly capture images of the sky positions reconstructed for promising transient gravitational-wave signal candidates. An EM counterpart, if detected, could help confirm a signal candidate as a real event and would yield valuable information about the progenitor and the astrophysics of the event. LOOC-UP and Swift ToO are projects with the goal to locate and observe these optical phenomena. In this poster we describe the methodologies and operations of these projects during the joint LIGO-Virgo run.

433

Instrumentation, Surveys and Data Poster Session *Exhibit Hall*

433.01

WHIMEX: An Explorer for High Resolution X-ray Spectroscopy of the Intergalactic Medium Webster C. Cash, Jr.¹, Whimex Science and Instrument Teams

¹Univ. of Colorado.

Exhibit Hall

With the further deferral of the International X-ray Observatory, there is a need for low cost approaches to high resolution x-ray spectroscopy. WhimEx is a mission concept that will be proposed in response to the current Explorer AO. WhimEx combines the teams and the technology that were being developed for the IXO reflection grating spectrometer. With WhimEx, astronomers will be able to probe the WHIM, AGN outflows and many other classes of x-ray sources in a manner similar to how Copernicus, FUSE and COS have in the ultraviolet.

Implementation of a 4x8 NIR and CCD Mosaic Focal Plane Technology

Patrick Jelinsky¹, C. J. Bebek², R. W. Besuner², G. M. Haller³, S. E. Harris¹, P. A. Hart³, H. D. Heetderks¹, M. E. Levi², S. E. Maldonado³, N. A. Roe², A. J. Roodman³, L. Sapozhnikov³

¹UC, Berkeley, ²Lawrence Berkeley National Laboratory, ³SLAC National Accelerator Laboratory. Exhibit Hall

Mission concepts for NASA's Wide Field Infrared Survey Telescope (WFIRST), ESA's EUCLID mission, as well as for ground based observations, have requirements for large mosaic focal planes to image visible and near infrared (NIR) wavelengths. We have developed detectors, readout electronics and focal plane design techniques that can be used to create very large scalable focal plane mosaic cameras. In our technology, CCDs and HgCdTe detectors can be intermingled on a single, silicon carbide (SiC) cold plate. This enables optimized, wideband observing strategies. The CCDs, developed at Lawrence Berkeley National Laboratory, are fully-depleted, p-channel devices that are backside illuminated capable of operating at temperatures as low as 110K and have been optimized for the weak lensing dark energy technique. The NIR detectors are 1.7µm and 2.0µm wavelength cutoff H2RG[®] HgCdTe, manufactured by Teledyne Imaging Sensors under contract to LBL. Both the CCDs and NIR detectors are packaged on 4side abuttable SiC pedestals with a common mounting footprint supporting a 44.16mm mosaic pitch and are coplanar. Both types of detectors have direct-attached, readout electronics that convert the detector signal directly to serial, digital data streams and allow a flexible, low cost data acquisition strategy, despite the large data volume. A mosaic of these detectors can be operated at a common temperature that achieves the required dark current and read noise performance in both types of detectors necessary for dark energy observations. We report here the design and integration for a focal plane designed to accommodate a 4x8 heterogeneous array of CCDs and HgCdTe detectors. Our current implementation contains over 1/4-billion pixels.

433.03

Wide Field InfraRed Survey Telescope (WFIRST) Science Yield

Michael Levi¹, M. Lampton², M. Sholl²

¹Lawrence Berkeley Lab., ²Space Sciences Laboratory.

Exhibit Hall

The Wide-Field Infrared Survey Telescope mission (WFIRST) is the Decadal Survey's highest recommended space mission. Its three mandates are (1) to study dark energy via measurement of the expansion history of the universe and the growth of large-scale structure, thereby providing tight constraints on the equation of state of dark energy and test the validity of general relativity; (2) to conduct intensive imaging of selected regions for exoplanet microlensing; and (3) to provide a general purpose surveying capability for the near infrared waveband. During the coming year, a Science Definition Team will be empaneled to prioritize the mission payload features and operations plans. To begin the misson definition process, we present four alternative WFIRST concepts and compare their quantitative science yields based on survey rates. We contrast these with alternative missions that have been proposed previously. Our WFIRST calculations are based on a newly developed unobscured focal TMA optical concept offering distinct simultaneous focal lengths for imaging and spectroscopy, reported in a companion poster by Sholl et al, and on a large modular focal plane concept reported on on a companion poster by Jelinsky et al. With these advances, we show that WFIRST can deliver a science yield superior to previously discussed dark energy and exoplanet missions.

A Practical Implementation of the Wide Field InfraRed Survey Telescope WFIRST Michael Sholl¹, M. L. Lampton¹, M. E. Levi²

¹University of CA Berkeley Space Sciences Laboratory, ²Lawrence Berkeley National Laboratory. Exhibit Hall

The Wide-Field Infrared Survey Telescope mission (WFIRST) combines a wide field imager and a wide field slitless spectrometer. It is intended to study dark energy via measurement of the expansion history of the universe and the growth of large-scale structure, and to provide tight constraints on the equation of state of dark energy and test the validity of general relativity. In addition, this mission will survey the Galactic Bulge for exoplanet microlensing events, delivering a rapid reobservation cadence for extended periods of time. During this past year we have developed optical techniques that deliver a well-corrected long focus image field simultaneously with a short focus spectroscopic field using a corrected prism disperser and a focal reducer. This advance allows unprecedented survey rates for combined BAO and WL surveys. Other payload features allow extended dwell times on the Galactic Bulge for microlensing. We present four practical implementations of the WFIRST payload that can meet the anticipated mission requirements. Options for simultaneous or staggered imaging and spectroscopy as well as the required plate scale change with a focal TMA are presented along with payload accommodation study results.

433.05

Moderate Resolution Near-IR Silicon Grisms For NIRCAM On JWST

Casey Deen¹, M. Gully-Santiago¹, W. Wang¹, D. T. Jaffe¹, D. Kelly², T. P. Greene³ ¹University of Texas at Austin, ²Steward Observatory, ³NASA Ames Research Center. Exhibit Hall

We report on the fabrication, metrology, and possible future astronomical uses for a suite of etched silicon grisms for use in NIRCAM on JWST. While the grisms will be initially used to align the JWST mirror segments, they are of high optical quality, excellent throughput, and can provide astronomers the opportunity for near-infrared moderate resolution ($R \sim 3000$) slitless spectroscopy.

433.06

The Mid-Infrared Instrument for the James Webb Space Telescope

Dean C. Hines¹, G. S. Wright², G. H. Rieke³, A. C. H. Glasse², M. E. Ressler⁴, MIRI Team ¹Space Telescope Science Institute, ²UK Astronomy Technology Centre, United Kingdom, ³The University of Arizona, ⁴Jet Propulsion Laboratory.

Exhibit Hall

The Mid-Infrared Instrument (MIRI) to be flown onboard the James Webb Space Telescope (JWST) provides direct and coronagraphic imaging, and integral field spectroscopic measurements over the wavelength range 5 - 28 μ m. We present an overview of the instrument and the current status of its construction.

Support for MIRI is provided by MIRI European National Funding Agencies, NASA and ESA.

433.07

On-Sky Performance and Science Survey Plans with FLAMINGOS-2

Stephen S. Eikenberry¹, FLAMINGOS-2 Early Science Survey Teams

¹Univ. of Florida.

Exhibit Hall

The FLAMINGOS-2 instrument achieved high-quality first-light observations on the Gemini South telescope in September 2009 was accepted by the Gemini Observatory and began scientific commissioning in December 2009 and January 2010, after which Gemini decided to take FLAMINGOS-2

off-line for a science array replacement. Based on the results so far, FLAMINGOS-2 (F2) on the Gemini 8meter telescope is an extremely powerful wide-field near-infrared imager and multi-object spectrograph. I will review the on-sky measured performance of FLAMINGOS-2 in imaging and spectroscopic observations. Furthermore, in order to take best advantage of the strengths of F2 early in its life cycle, we propose to use 21 nights of Gemini guaranteed time in 3 surveys - the FLAMINGOS-2 Early Science Surveys (F2ESS). The F2ESS will encompass 3 corresponding scientific themes - the Galactic Center, extragalactic astronomy, and star formation. I will also review the plans for carrying out these surveys with F2, data analysis plans and software, and the expected scientific impact from this powerful new observational tool.

433.08

Prototype Development of the GMT Fast Steering Mirror

Young-Soo KIM¹, K. Park¹, J. Koh¹, E. Kim¹, J. Kyeong¹, I. Yuk¹, B. Park¹

¹KASI, Korea, Republic of.

Exhibit Hall

Fast Steering Mirror (FSM) is one of the secondary mirror systems of Giant Magellan Telescope, enabling tip-tilt compensation of image degradations caused by wind and structure jitter. FSM consists of seven segments, and each segment contains a lightweight mirror, mirror cell with supports, and vacuum sub-system. Tip-tilt mechanism is implemented in the axial supports of each segment.

Korea Astronomy and Space Science Institute is developing a prototype of the FSM together with collaborators in Korea and USA. The prototype is a full-size FSM segment, which is divided into two parts; an off-axis mirror and a test-bed for tip-tilt actuation. The off-axis mirror with diameter of 1.06m will be fabricated by light-weighting, polishing, figuring, and testing. The tip-tilt test-bed is assembled by a dummy mirror, three axial supports, a lateral support, and a test-bed frame. The test-bed will be used for verifying the tip-tilt parameters and checking reaction forces. The prototype is expected to be completed by early 2012. In this paper, we present the plan and current status of the prototype development, and discuss future works.

433.09

Spectrophotometric Calibration System for DECam

Jean-Philippe Rheault¹, D. DePoy¹, J. Marshall¹, D. Carona¹, K. Cook¹, T. Behm¹, R. Allen¹

¹Texas A&M University. Exhibit Hall

We present a spectrophotometric calibration system that will be implemented as part of the DES DECam project at the Blanco 4 meter at CTIO. Our calibration system uses a 2nm wide tunable source to measure the instrumental response function of the telescope from 300nm up to 1100nm. This calibration will be performed at regular interval during the survey to monitor any change in the transmission function. The system consists of a monochromator based tunable light source that provides illumination on a dome flat that is monitored by calibrated photodiodes and allow us to measure the throughput as a function of wavelength. Our system has an output power of 2 mW, equivalent to a flux of approximately 800 photons/s per pixel on DECam. We also present results from the deployment of a prototype of this system at the Swope and DuPont telescopes at Las Campanas Observatory for the calibration of the photometric equipment used in the Carnegie Supernova Project.

A 150 GHz Receiver Module for Astronomical Observations

Patricia Voll¹, J. Lau¹, M. Sieth¹, S. Church¹, L. A. Samoska², P. P. Kangaslahti², M. Soria², T. C. Gaier², D. Van Winkle³, S. Tantawi³

¹Stanford University, ²Jet Propulsion Laboratory (JPL), ³SLAC National Accelerator Laboratory. Exhibit Hall

A compact, wide-band, heterodyne amplifier module has been designed to operate in the 150 GHz atmospheric window using High Electron Mobility Transistor (HEMT) amplifier technology. This frequency range is important for many astrophysical science applications, including spectral line studies, separating the cosmic microwave background (CMB) radiation from foregrounds, and detecting the hot gas around galaxy clusters using the Sunyaev-Zeldovich effect. HEMT-based receiver arrays with excellent noise and scalability are already being manufactured around 100 GHz, but recent advances have made it possible to extend this technology to even higher frequencies. The prototype 150 GHz module housing utilizes Monolithic Millimeter-Wave Integrated Circuit (MMIC) InP Low Noise Amplifiers (LNAs). These amplifiers, along with a second harmonic mixer, bias circuitry, and connectors, are contained in a single, split-block housing approximately one inch cubed in size. Preliminary cryogenic tests have measured a system noise temperature of 150 K over a bandwidth of 25 GHz with a minimum noise temperature of less than 100 K at 168 GHz. The minimum noise temperature is less than 100 K at 168 GHz. Module improvements for the second phase are expected to reduce the noise temperature to the minimum allowed by the device limit. Development of a 4-element array to demonstrate the scalability of these receivers is currently underway, and will serve as a prototype for much larger, 100element arrays for astrophysical applications. In the future, a space mission incorporating an array of these modules could be used to detect the curl modes (B-modes) of the CMB polarization, which is important for the search for the signature of inflation.

433.11

The Pomona College PINTO Internet telescope and Near Earth Asteroid Research

Bryan Edward Penprase¹, A. Hagen², D. Trilling², C. Wilka¹

¹Pomona College, ²Northern Arizona University.

Exhibit Hall

We present the results of a remotely operated telescope known as PINTO, the Pomona College Internet Telescope, and the campaign for monitoring a sample of Near Earth Asteroids. We have observed over 150 asteroids with the system, and we present some of the details of the Python-based robotic control system, and our data reduction pipeline. Our PINTO telescope is based in New Mexico, but is controlled by a set of Python routines that generate NEO ephemeris data, schedule and execute observations, and automatically sequence the observations with standard star observations. In addition, we have enabled our Claremont, CA telescopes for remote operation, and we describe some of our plans for using the network of telescope for asteroid study and transient followup.

433.12

The GMACS Spectrograph for GMT

Jennifer L. Marshall¹, D. L. DePoy¹, S. A. Shectman², S. A. Smee³, R. H. Barkhouser³, T. M. Prochaska¹, G. J. Hill⁴

¹Texas A & M University, ²Carnegie Observatories, ³JHU/IDG, ⁴University of Texas at Austin. Exhibit Hall

We describe a conceptual design for a wide field, multi-object,

moderate-resolution optical spectrograph (known as GMACS) for

the Giant Magellan Telescope (GMT). The crucial design drivers for

the instrument are high throughput, simultaneous wide wavelength coverage over the entire optical window, and accurate and precise sky subtraction. The range of science projects enabled by the instrument is huge: from mineralogical studies of distant asteroids and KBOs to stellar population studies of high redshift galaxies.

433.13

A turn-key Concept for active cancellation of Global Positioning System L3 Signal

Lou Nigra¹, B. M. Lewis², C. E. Edgar³, P. Perillat², L. Quintero², S. Stanimirovic¹, J. S. Gallagher, III¹ ¹University of Wisconsin, ²National Astronomy & Ionosphere Center, Puerto Rico, ³The Aerospace Corporation.

Exhibit Hall

We present a concept, developed at the National Astronomy and Ionosphere Center (NAIC) at Arecibo, Puerto Rico, for suppression of Global Positioning System (GPS) signals in the 305 m dish radio receiver path prior to backend processing. The subsystem does not require an auxiliary antenna and is intended for easy integration with radio telescope systems with a goal of being a turnkey addition to virtually any facility. We have focused on detection and cancellation of the GPS L3 signal at 1381.05 MHz which, during periodic test modes and particularly during system-wide tests, interfere with observations of objects in a range of redshifts that includes the Coma supercluster, for example. The signal can dynamically change modulation modes and our scheme has demonstrated, through simulations using actual sampled telescope data, the ability to acquire and track these signals as well as detect the mode changes in order to apply cancellation or blanking, as appropriate. The subsystem can also be adapted to GPS L1 (1575.42 MHz), L2C (1227.6 MHz), and others. A follow-up is underway to develop a prototype to deploy and evaluate at NAIC.

433.14

KAPAO: A Pomona College Adaptive Optics Instrument

Philip I. Choi¹, S. A. Severson², A. R. Rudy¹, B. N. Gilbreth², D. S. Contreras¹, L. P. McGonigle¹, R. M. Chin¹, B. Horn³, O. Hoidn³, E. Spjut³, C. Baranec⁴, R. Riddle⁴

¹Pomona College, ²Sonoma State University, ³Harvey Mudd College, ⁴California Institute of Technology. Exhibit Hall

We describe our project (KAPAO) to develop and deploy a low-cost, remote-access, natural guide star adaptive optics system for the Pomona College Table Mountain Observatory (TMO) 1-meter telescope. The system will offer simultaneous dual-band, diffraction-limited imaging at visible and near-infrared wavelengths and will deliver an order-of-magnitude improvement in point source sensitivity and angular resolution relative to the current TMO seeing limits. In order to ensure reliability, minimize costs and encourage replication efforts, off-the-shelf components that include a MEMS deformable mirror, a Shack-Hartmann wavefront sensor and a piezo-electric tip-tilt mirror are being adopted for the core hardware elements. We present: the instrument design; performance predictions based on AO simulations; and the current status of the testbed instrument and high-speed control system. Beyond the expanded scientific capabilities enabled by AO-enhanced resolution and sensitivity, the interdisciplinary nature of the instrument development effort provides an exceptional opportunity to train a broad range of undergraduate STEM students in AO technologies and techniques. The breadth of our collaboration, which includes both public (Sonoma State University) and private (Pomona and Harvey Mudd Colleges) undergraduate institutions has enabled us to engage students ranging from physics, astronomy, engineering and computer science in the early stages of this project. This material is based upon work supported by the National Science Foundation under Grant No. 0960343.

433.15 Astra: Dual-field And Astrometry With The Keck Interferometer Julien $\mbox{Woillez}^1$

¹W.M. Keck Observatory.

Exhibit Hall

Funded in 2006 by an NSF MRI grant, the ASTRA project aims at improving the capability of the Keck interferometer by providing a spectro-interferometric mode for R~2000 spectroscopy in the K band, a phase referencing mode to reach K~14 magnitude, and an astrometric mode for 100-30 micro-arcsecond narrow angle astrometry. These improvements cover a broad range of astrophysical topics including Young Stellar Objects, Active Galactic Nuclei, the Galactic Center, and known Exo-planets.

433.16

The Dark Energy Survey: Survey Strategy

James T. Annis¹, C. Cunha², M. Busha³, Z. Ma⁴, DES Collaboration ¹Fermi National Accelerator Laboratory, ²University of Michigan, ³SLAC, ⁴Brookhaven National

Laboratory. Exhibit Hall

The Dark Energy Survey uses 525 nights over 5 years of time on the CTIO Blanco 4m telescope to image 5000 sq-degrees of the South Galactic Cap in 5 filters while also performing a roughly 15 sq-degree time domain survey for supernovae. The survey strategy is designed to optimize three things: our ability to do cluster and LSS science early in the survey, our ability to do weak lensing, and our ability to collect an cosmologically interesting sample of supernovae. Thus we cover the entire survey area twice per year per bandpass (grizY, i > 24); we devote the best seeing time to the main survey; and we observe the SN fields at high cadence over 5-6 months while minimizing observation gaps of a week or more. We have chosen survey metrics which report survey area covered given a fiducial exposure time (the equivalent number of tilings), and an estimate of the total number of galaxies useful for weak lensing that is essentially a non-linear combination of signal to noise and seeing (the effective number of galaxies, n_eff). We have developed photo-z simulations given survey strategy parameters, and these along with the area covered, the depth achieved and n eff allow us to estimate the figure of merit for our LSS, clusters, and weak lensing projects to judge the the ability of the each scenario to maximize the DETF FOM. We have developed a tool that uses the extensive weather and seeing data available for CTIO to simulate the survey. The poster will describe the current survey strategy and the results that support each choice.

433.17

A 5000-hour Meerkat Large Survey Project To Observe Hi To Z=1

Benne W. Holwerda¹, S. Blyth², A. J. Baker³, MeerKAT Deep HI Survey Team

¹European Space Agency, Netherlands, ²University of Cape Town, South Africa, ³Rutgers University. Exhibit Hall

The MeerKAT (64 x 13.5m dish radio interferometer) is South Africa's precursor instrument for the Square Kilometre Array (SKA), exploring dish design, instrumentation and the site in the Karoo desert. MeerKAT is projected to be on sky in 2015. One of two approved, top-priority, Key Projects, is a single deep field, integrating for 5000 hours total with the aim to detect neutral atomic hydrogen through its 21 cm line emission out to redshift unity.

This first truly deep HI survey will help constrain fueling models for galaxy assembly and evolution, the evolution of cosmic neutral gas density of the Universe over cosmic time, evolution in the star-formation law (the Schmidt-Kennicutt law), distance indicators such as the Tully-Fisher relation, and much more. Here we present the specifications, timeline, and envisaged science case for this unique deep field,

which encompasses the Chandra Deep Field-South (and the footprints of GOODS, GEMS and several other surveys) to produce a singular legacy multi-wavelength data-set.

433.18

La Silla-QUEST Variability Survey

Elena I. Hadjiyska¹, D. Rabinowitz¹, C. Baltay¹, R. Zinn¹, P. Coppi¹, N. Ellman¹, L. R. Miller¹

¹Yale University.

Exhibit Hall

The La Silla-QUEST (LSQ) Variability Survey is a dedicated wide field synoptic survey, focusing on the discovery and study of transients ranging from low redshift (z < 0.1) SN Ia, Tidal Disruption events, RR Lyrae variables, CVs, Quasars, TNOs and others. The survey utilizes the 1.0-m Schmidt Telescope of the European Southern Observatory at La Silla, Chile with the large area QUEST camera, a mosaic of 112 CCD's with field of view of 9.6 square degrees. The QUEST camera was previously installed on the 1.2-m Oschin Schmidt at Palomar and was responsible for the detection of several hundred nearby supernovae for the Berkeley Supernova Factory, studies of quasar and blazar variability, and the discovery of dwarf planets in the outer solar system. The LSQ Survey was commissioned in 2009, and is now regularly surveying ~1000 square deg per night with a repeat cadence of hours to days. The data are currently processed on a daily basis though the Yale photometry pipeline. We present here a first look at the photometric capabilities of LSQ, including light curves of known SN and RR Lyrae stars, and we discuss the future goals of the survey.

433.19

Large Survey Database: A Distributed Framework for Storage and Analysis of Large Datasets Mario Juric^1

¹Harvard University.

Exhibit Hall

The Large Survey Database (LSD) is a Python framework and DBMS for distributed storage, crossmatching and querying of large survey catalogs (>10^9 rows, >1 TB). The primary driver behind its development is the analysis of Pan-STARRS PS1 data. It is specifically optimized for fast queries and parallel sweeps of positionally and temporally indexed datasets. It transparently scales to more than >10^2 nodes, and can be made to function in "shared nothing" architectures.

An LSD database consists of a set of vertically and horizontally partitioned tables, physically stored as compressed HDF5 files. Vertically, we partition the tables into groups of related columns ('column groups'), storing together logically related data (e.g., astrometry, photometry). Horizontally, the tables are partitioned into partially overlapping ``cells'' by position in space (lon, lat) and time (t). This organization allows for fast lookups based on spatial and temporal coordinates, as well as data and task distribution. The design was inspired by the success of Google BigTable (Chang et al., 2006). Our programming model is a pipelined extension of MapReduce (Dean and Ghemawat, 2004). An SQL-like query language is used to access data. For complex tasks, map-reduce ``kernels'' that operate on query results on a per-cell basis can be written, with the framework taking care of scheduling and execution. The combination leverages users' familiarity with SQL, while offering a fully distributed computing environment.

LSD adds little overhead compared to direct Python file I/O. In tests, we sweeped through 1.1 Grows of PanSTARRS+SDSS data (220GB) less than 15 minutes on a dual CPU machine. In a cluster environment, we achieved bandwidths of 17Gbits/sec (I/O limited). Based on current experience, we believe LSD should scale to be useful for analysis and storage of LSST-scale datasets. It can be downloaded from http://mwscience.net/lsd.
433.20 Microstructure Formation in Stellar Shock Propagation Earl Nicholas¹

¹*Michigan State University.*

Exhibit Hall

Using ENZO, a cosmological adaptive mesh refinement (AMR) code, and YT, a python package used to analyze AMR data, we run simulations of shockwave propagation through a variously characterized medium at high-resolutions. The characteristics of the shock itself are similarly varied. We then analyze the dependence of microstructure formation in the propagating shock on conditions of velocity, density, temperature, and metallicity of both the shock and medium. Advancing the simulation, we allow the instabilities to develop to some derived time based on initial conditions. We find strong correlations between particle density, temperature, and metallicity in determining the features of the shock column, the development of thick or thin 'fingers', and the distribution of energy, metals, and propagated material. We found the most interesting results when using temperatures in the range of 1,000K to 10,000K, shock velocities of 2 to 8 times the sound speed, densities of 10 to 100 particles per cubic centimeter, and metallicities of 0 to 2.2e-4, with analytic comparisons of parameter sets with and without a metal cooling mechanism, however we do maintain radiative cooling. We examine the significance of these results and what they may suggest in discussions of material propagation between generations of stars. Implications of interstellar enrichment are also considered.

433.21

Automated Classification of Eclipsing Binary Stars Using Fourier Descriptors and Artificial Neural Networks

Katherine Leaveck¹, S. Goderya¹, B. Little¹

¹*Tarleton State University.*

Exhibit Hall

Photometric observation of stars has drastically increased the number of known variable stars to a point where traditional object-by-object analysis is not feasible. Using artificial neural networks for data mining, data reduction and analysis is of great interest to astronomers who now have more data readily available than any person or team could analyze in a lifetime. This poster presents efforts to build a scheme to automatically classify light curves of eclipsing binary stars using Fourier descriptors and artificial neural networks. The raw data was obtained from available public domain databases and a FORTRAN code was written to compute the Fourier descriptors. The Fourier descriptors are presented as inputs to the supervised neural network for training and classifying the light curves. The efficacy of using Fourier descriptors was determined by calculating correlation coefficients using a FORTRAN program. The results of these experiments showed acceptable correlation between the mathematical features represented by the Fourier descriptors and the light curves. The results described here are based on the data available in the public domain.

433.22

The Exploration Of Massive Multi-wavelength Astronomical Datasets: The Chandra Source Catalog Case

Raffaele D'Abrusco¹, G. Fabbiano¹, G. Djorgovski², M. Elvis¹, A. Lawrence³, G. Longo⁴ ¹Harvard-Smithsonian Center for Astrophysics, ²California Institute of Technology, ³Institute for Astronomy, United Kingdom, ⁴University "Federico II", Italy. Exhibit Hall

With the availability of very large datasets covering almost completely the electromagnetic spectrum and the advent of new technologies allowing easy retrieval and accurate federation of such data,

astronomical community is ready to harness the wealth of information available in the multi-wavelength domain through data mining techniques. In this talk I will present the rationale and first results of a project

involving the exploration of the multi-wavelength distribution of a sample of X-ray selected AGNs, extracted

from the Chandra Source Catalogue, in the parameter space obtained by combining data from several observations at different wavelengths, spanning from X-rays to radio. The goal of this project is to achieve

a consistent clustering of AGNs and hopefully determine new correlations that might be used to achieve an objective classification scheme and identify new peculiar rare classes of AGNs.

433.23

Applying Observational Methods to Images of a Simulated High-Redshift Universe Robert J. Morgan¹, E. Scannapieco¹, R. Thacker², R. A. Windhorst¹ ¹Arizona State Univ., ²St. Mary's University, Canada. Exhibit Hall

Flexible Image Transport (FITS) images produced from numerical cosmological simulations of dark and baryonic matter are analyzed using Source Extractor (SExtractor), a tool frequently used in observational image analysis. The goal is to assist the interpretation of simulation by better understanding how simulation data might appear in the observational domain.

The simulation model, based on Gadget-2 (Springel and Hernquist, 2003) includes gas heating, cooling and star formation. The stellar components of the model are processed by the Bruzual-Charlot (BC03) stellar population models to produce SEDs (Spectral Energy Distributions). These are then folded with different infrared filters, including selected filters from WFC3 and the proposed Near Infrared Camera (NIRCam) for the James Webb Space Telescope (JWST). The simulation data are taken at different redshifts from z~4 to 11, re-sized according to their comoving distances, converted to FITS format files and combined with noise to simulate instrument and background effects. The images are then analyzed with SExtractor to find groupings which are identified as galaxies or galaxy building blocks. Photometry is performed on these objects using SExtractor to extract luminosity functions in the emitted rest frames. Initially, minimal noise levels are used to allow fine details of the model to be "observed." More realistic sky background levels are then added to estimate the effect of artifacts of observation.

We use these models to predict the faint-end Schechter slope evolution alpha(z). We compare these models to the most recent Hathi et al. (2010, ApJ, 720, 1708) data, and find good agreement in the faint end slope evolution: predicted alpha (7>z>5) = -1.7 to -1.8, observed alpha (z>5) = -1.75.

433.24

Creation of White Dwarf Photospheres in the Laboratory

Jennifer Ellis¹, R. E. Falcon¹, G. A. Rochau², D. E. Winget¹, J. E. Bailey², M. H. Montgomery¹ ¹University of Texas at Austin, ²Sandia National Laboratories.

Exhibit Hall

We measure the Stark dominated, hydrogen line broadening in macroscopic plasmas with temperatures and electron densities typical of white dwarf photospheres. Utilizing the large X-ray flux generated by the Z Pulsed Power Facility at Sandia National Laboratories, NM, we uniformly heat a 19 cm³ cell of hydrogen gas to the relevant conditions, taking time resolved measurements of the emission spectra. The experiment will cover a wide range of white dwarf photospheric plasma conditions and compositions, testing not only theoretical white dwarf atmosphere models, but also current line broadening theories, with empirical measurements in unexplored regimes.

433.25

Can Astronomers Meet Engineering Needs? Leonard J. Berg¹

¹The Boeing Company.

Exhibit Hall

Spacecraft that require high-accuracy pointing use stars to establish and maintain an attitude reference. These systems require accurate data for the brightest stars in the sky. In the past, astronomers routinely observed the bright stars, easily outdistancing the requirements of the spacecraft navigation community. Today, however, a demand for increasingly accurate systems is paired with diminishing scientific interest in the bright stars used for engineering applications.

433.26

Polaris Instrument Development and PARI Experience Nathan Stewart $^{\!\!\!1}$

¹J Don Cline, PARI, UNC Pembroke.

Exhibit Hall

At the Pisgah Astronomical Research Institute (PARI) in Rosman, NC I spent 8 weeks as the NC Space Grant/J. Donald Cline Astronomy Scholar. I developed multiple projects and assisted as a mentor to PARI Space Science Lab and Duke TIP high school gifted student program which both took place during my stay. My main focus was the development of the Polaris imaging telescope. This telescope is used to take images of the pulsating variable star Polaris. These readings are used to make seeing estimates for the air column above PARI. The system stores and archives images and analyzes them for magnitude change and movement of the stellar image. In addition to the Polaris project I developed a solar panel voltage and charge monitoring system which involved me working with charge controllers and photovoltaic technology. I developed a charging scheme using Flexmax 60 charge controller. Data is recorded and transmitted via optical fiber for analysis and correlation with solar zenith angle.

434

Stars, Star Formation and Associated Topics Poster Session *Exhibit Hall*

434.01

When a Standard Candle Flickers

Colleen Wilson¹, M. L. Cherry², G. L. Case², W. H. Baumgartner³, E. Beklen⁴, P. N. Bhat⁵, M. S. Briggs⁵, A. Camero-Arranz⁶, V. Chaplin⁵, V. Connaughton⁵, M. H. Finger⁷, N. Gehrels⁸, J. Greiner⁹, K. Jahoda⁸, P. Jenke¹, R. M. Kippen¹⁰, C. Kouveliotou¹, H. Krimm¹¹, E. Kuulkers¹², N. Lund¹³, C. A. Meegan⁷, L. Natalucci¹⁴, W. S. Paciesas⁵, R. Preece⁵, J. C. Rodi², N. Shaposhnikov¹¹, G. K. Skinner¹¹, D. Swartz⁷, A. von Kienlin⁹, R. Diehl⁹, X. Zhang⁹

¹NASA's MSFC, ²LSU, ³CRESST/NASA/GSFC, ⁴METU/SDU, Turkey, ⁵UAH, ⁶NSSTC, ⁷USRA, ⁸NASA/GSFC, ⁹MPE, Germany, ¹⁰LANL, ¹¹UMD/CRESST/NASA/GSFC, ¹²ISOC/ESA/ESAC, Spain, ¹³Danish National Space Center, Denmark, ¹⁴INAF-IASF, Italy.

Exhibit Hall

The Crab Nebula has been used as a normalization standard by most X-ray/gamma ray telescopes. Although small-scale variations in the nebula are well-known, in the first two years of science operations of the Fermi Gamma-ray Burst Monitor (GBM), a ~7 (70 mcrab) decline has been observed in the overall Crab Nebula flux in the 15 - 50 keV band, measured with the Earth occultation technique. This decline is independently confirmed in the ~15-50 keV band with three other instruments: Swift/BAT, the RXTE/PCA, and INTEGRAL/IBIS. A similar decline is also observed in the ~3-15 keV data from the RXTE/PCA and in the 50-100 keV band with GBM, Swift/BAT, and INTEGRAL/IBIS. The pulsed flux measured with RXTE/PCA since 1999 is consistent with the pulsar spin-down, indicating that the observed changes are nebular. Correlated variations in the Crab Nebula flux on a ~3 year timescale are also seen independently with the PCA, BAT, and IBIS from 2005 to 2008, with a flux minimum in April 2007. As of August 2010, the current flux has declined below the 2007 minimum.

434.02

A Search for Optical Counterparts for Three RRATs

Melvin Blake¹, D. Johnson¹

¹University of North Alabama.

Exhibit Hall

Rotating Radio Transients were discovered in 2006 as a result of data mining of the Parkes survey for transient objects. The 11 Rotating Radio

Transients (RRATs) seem to be a unique class of pulsars which burst for short periods and when in outburst can be among the most radio-bright objects in the sky. The place these objects occupy in the evolution of pulsars in still an active area of investigation. We report here one of the first attempts to identify optical counterparts to RRATs. The data were obtained with the 0.4m robotic PROMPT telescopes during automated observing. Our data consists of VRI and I-band imaging of three RRATs, J144360, J13175759 and J084843. While several candidate variable stars

seem to be present in the data, we did not detect any transient sources coincident with the RRATs.

434.03

Kinetic Dissipation of Strongly Magnetized Relativistic Outflow and the Sigma Problem Edison P. Liang 1

¹Rice Univ..

Exhibit Hall

Many high energy astrophysical phenomena involve strongly magnetized relativistic outflows, from pulsar wind to gamma ray burst. How these objects efficiently convert their Poynting flux into energetic particles and radiation remains one of the outstanding unsolved problems in astrophysics (the "Sigma Problem"). Here we present Particle-in-Cell (PIC) kinetic simulations of direct Poynting flux conversion into particle energy in the context of pulsar equatorial stripe wind. We show how comoving ponderomotive (JxB) acceleration due to self-generated polarization-drift currents can efficiently convert electromagnetic energy into accelerated particles in an overdense but high a0 (= dimensionless vector potential) plasma. We study the dissipation rate as a function of Lorentz factor, magnetic field strength and orientation.

Work supported by NSF AST-0909167 and DOE-DE-SC-0001481.

434.04

Psr J1903+0327 - A Unique Milli-second Pulsar System

Juthika Khargharia¹, J. Stocke¹, C. Froning¹

¹University of Colorado.

Exhibit Hall

We obtained three epochs of GMOS-N spectroscopy data of the likely companion to a unique new milli-second pulsar in a highly eccentric orbit. Pulsar timing provides an accurate mass for the companion star (1M) and its orbital period (95 days). Near-IR images detect a star at the pulsar position with colors consistent with a highly-reddened G star. If it can be shown that the G star is

the only companion, then this system will provide new tests of General Relativity. Here, we present our preliminary results on the association of the possible companion star to the pulsar system.

434.05

Measuring Gamma-ray Pulsar Glitches With Fermi-lat **Michael Dormody**¹, Fermi Collaboration

¹UCSC.

Exhibit Hall

The Fermi-LAT has collected over two years of nearly continuous photon data since its launch in June 2008. These continuous observations allow us to study long-term timing behavior of pulsars, including timing noise and glitches. While pulsars are well modeled steady clocks, large jumps in rotational frequency ("glitches") can occur. These glitches are thought to be due to a sudden transfer of angular momentum from a seismic event, and studying glitch parameters can illuminate neutron star structure. We present glitch information on the thus-far observed 11 glitching Fermi-LAT gamma-ray pulsars from the first 2 years of operation, including glitch parameters and a variability analysis.

434.06

AGILE Discovery of Gamma-ray Flares from the Crab Nebula Marco Tavani¹

¹INAF-IASF Roma and University of Rome Tor Vergata, Italy. Exhibit Hall

We will summarize the AGILE data leading to the very significant discovery of a variable flaring gammaray flux from the Crab Nebula. Both the September 2010, and previous flaring episodes will be discussed, with particular emphasis on the spectral behavior and evolution. The physical origin of the flaring phenomenon will be addressed, with a focus on particle acceleration processes occurring in the nebula.

434.07

The Properties of the Progenitor Supernova and Central Neutron Star in Pulsar Wind Nebula PWN G54.1+0.3

Joseph Gelfand¹, P. O. Slane²

¹New York University Abu Dhabi, United Arab Emirates, ²Harvard-Smithsonian Center for Astrophysics. Exhibit Hall

By comparing the predicts of a semi-analytic model for the evolution of a pulsar wind nebula inside a supernova remnant with the observed dynamical and radiative properties of PWN G54.1+0.3 we are able to constrain the properties of the progenitor supernova and the birth properties of the central neutron star. This has significant implications for both the progenitor star of this system and the magnetosphere of this pulsar.

434.08

Cataclysmic Variables from the Chandra Multi-wavelength Plane Survey

Ping Zhao¹, J. Grindlay¹, J. Hong¹, M. Servillat¹, M. van den Berg¹, S. Laycock² ¹Harvard-Smithsonian, CfA, ²UMass.

Exhibit Hall

We present the Cataclysmic Variables discovered from the Chandra Multi-wavelength Plane Survey (ChaMPlane). ChaMPlane is designed to survey the point X-ray sources discovered by the Chandra X-ray Observatory in the galactic plane in order to constrain the X-ray binary population in the Galaxy. We have been conducting the ChaMPlane survey since year 2000. The survey includes the data from

the Chandra achieve, as well as the optical and infrared images and spectroscopes. CV candidates are first identified from the Chandra and optical imaging in the deep V, I, R, H-alpha bands. Then optical spectroscopic follow-ups are conducted to confirm their status. CVs are identified by their hydrogen Balmer and helium emission lines, often broadened and double peaked due to the accretion disk rotation around the primary. We present the spectra of 20 CVs obtained from the Magellan, CTIO-4m and WIYN telescopes.

434.09

The 2007 Outburst of GW Librae

Laura Vican¹, J. Patterson¹

¹Columbia University.

Exhibit Hall

In April of 2007, the dwarf nova GW Librae erupted for a second time. We report the results of the worldwide observing campaign of this outburst. Our data consists of 90 nights of time-series photometry obtained from several locations around the Earth.

GW Lib first erupted in 1983. Since then and until the 2007 eruption, GW Lib was quiescent at magnitude 16.6. During the 2007 eruption, the light rose sharply from V=13 to maximum light at V=8.3 in one day. The main eruption lasted 26 days, and was characterized by a roughly constant phase (the so-called "plateau phase") followed by a sudden drop to magnitude 15. The light then dimmed slowly toward quiescence.

GW Lib is a dwarf nova of short orbital period (77 minutes). During the eruption, the star showed the expected powerful superhumps in its light curve at a period slightly longer than the orbital period. A fractional period excess of 1.3% suggests a secondary star mass near 0.06 M \odot . These superhumps took 10 days to appear and lasted for at least 90 days after the peak of the eruption. This time frame agrees with the general idea that cataclysmic variables of short orbital period are actually quite old with small secondary stars that have been whittled away by mass transfer over eons of evolution. Analysis of accretion light during the outburst suggests L_{bol}=8(±2)×19³¹ ergs/s and M_{dot}=1.3(±0.3)×10⁻¹¹ M \odot /year.

434.10

Spitzer Observations of Unusually Red and Blue L Dwarfs

Sarah Garcia¹, A. J. Burgaser¹, M. C. Cushing², K. Cruz³, J. K. Faherty⁴

¹UCSD, ²NASA/JPL, ³Hunter College, ⁴American Museum of Natural History.

Exhibit Hall

We present Spitzer/IRAC measurements of a sample of unusually red and unusually blue L dwarfs, sources which are believed to have extreme cloud properties, surface gravities and/or metallicities. This sample includes a handful of L subdwarfs with halo kinematics. We compare the mid- and near-infrared colors of these sources to normal field L dwarfs, noting trends in surface gravity and metallicity. We also present Spitzer/IRS spectra of the unusually blue L dwarf 2MASS 1126-5003, in which the 8-10 micron silicate grain feature is weak or absent. This is consistent with the interpretation that this source has unusually thin or patchy photospheric clouds.

The Brown Dwarf Kinematics Project: Radial Velocities of M and L Dwarfs with MagE

Sarah Logsdon¹, A. J. Burgasser¹, J. J. Bochanski², B. Sitarski¹, S. Schmidt³, J. Faherty⁴, K. Cruz⁵, A. A. West⁶

¹University of California, San Diego, ²Pennsylvania State University, ³University of Washington, ⁴American Museum of Natural History/SUNY Stony Brook, ⁵Hunter College, ⁶Boston University. Exhibit Hall

We present preliminarily radial velocities of a sample of late M- and L-type dwarfs obtained with the Magellan Echellette (MagE) spectrograph on Magellan's 6.5m Clay telescope. The sources were chosen to have distances less than 20 parsecs from the Sun, and/or have unusual spectral energy distributions (e.g., subdwarfs, low surface gravity objects). Radial velocities were calculated from the line centers of prominent atomic absorbers (e.g., K I, Na I, Ca I, Cs I, Rb I) and cross-correlation with both SDSS M- and L-dwarf template standards from Bochanski et al. (2005) and MagE spectra of M- and L-dwarfs with measured radial velocities from the literature. We combine these radial velocities with proper motion and parallax measurements to calculate UVW velocities for our dwarf sample. We present preliminary analysis of velocity dispersions for the sample and examine correlations between kinematics and spectral activity, metallicity and age diagnostics. We also report the Galactic orbit of 2MASS J07075327-4900503, an unusually fast-moving dwarf in our sample.

434.12

Accurate Radial Velocities of 2284 FGKM Stars and 127 Standards

Carly Chubak¹, G. Marcy¹

¹UC Berkeley.

Exhibit Hall

We present radial velocities with an accuracy of 0.1 km/s for 2284 stars of spectral type F,G,K, and M, based on ~29000 spectra taken with the Keck I telescope. We also present 127 FGKM standard stars, all of which exhibit constant radial velocity within 0.01 km/s (RMS) for at least 10 years. All velocities are measured relative to the solar system barycenter and are placed on the velocity scale of Nidever et al (2002). Comparison of our absolute radial velocities with IAU standards shows agreement within 0.1 km/s. Small zero-point differences from the different spectrometers are well characterized. The quoted radial velocities contain no corrections for convective blueshift or gravitational redshift. The radial velocities presented here serve as standards for all-sky surveys such as Gaia and RAVE.

434.13

Searching for Brown Dwarfs and Brown Dwarf Binaries in Upper Scorpius, the Trapezium, and IC 348 Using the UKIDSS Galactic Cluster Survey

Marin M. Anderson¹, B. Biller²

¹University of California, Berkeley, ²Institute for Astronomy, University of Hawaii. Exhibit Hall

We conducted a survey of three young star forming regions using the UKIRT Infrared Deep Sky Galactic Cluster Survey (GCS) Database Release 7 to identify a sample of brown dwarf and brown dwarf binary system candidates. The known distances to and ages of the young star forming regions queried (the Upper Scorpius association, the Trapezium Cluster in Orion, and IC 348 in the Perseus OB Association) allow us to estimate masses for the candidate brown dwarfs, using appropriate evolutionary models (Chabrier et al. 2000, Baraffe et al. 2002, Baraffe et al. 1998).

Brown dwarf candidates were selected based on their infrared luminosity (J, H, and K bands) and a corresponding drop-off in shorter wavelength luminosity (Z and Y bands). A series of color cuts, taken from Lodieu et al., 2006, were applied to (Z - J, Z) color-magnitude diagrams to select the fainter, redder

candidates from the brighter sources in the survey regions. Cross-correlation of the GCS data with the 2MASS database provided a second epoch of information, further narrowing the list of brown dwarf candidates to only those proper motion members of the surveyed clusters.

The continued discovery and classification of young brown dwarfs in star forming regions allows us to better model the substellar initial mass function and understand sub-stellar formation processes. In particular, our survey of Upper Sco produced 170 brown dwarf and low-mass stellar candidates, and 4 candidate brown dwarf binary systems, which were used to derive a substellar IMF that corresponds well with other substellar IMFs found from previous surveys of different regions in Upper Sco. This work was conducted through a Research Experience for Undergraduates (REU) position at the University of Hawaii's Institute for Astronomy, with funding provided by the NSF.

434.14

Component Spectral Types of L- and T-Dwarf Binaries from Combined-Light Spectroscopy and Resolved Photometry

Emily C. Bowsher¹, A. Burgasser¹

¹University of California San Diego.

Exhibit Hall

Brown dwarf binaries are predominantly tightly-bound systems, generally resolved through highresolution imaging. While resolved photometry allows some characterization of the components of these systems, resolved spectroscopy is necessary to study their atmospheres in detail. However, such data has been difficult to obtain. Here we present an alternative method of extracting component spectroscopic information, through the application of a constrained spectral template matching technique. We compare combined-light near-infrared spectra of fifteen L- and T-dwarf binaries to binary templates drawn from the SpeX Prism Spectral Libraries, with each template constrained by at least three relative magnitude measurements. For these, we infer the component spectral types and relative JHK magnitudes of the binaries and detail the degree of J-band brightening for binaries stradling the Ldwarf/T-dwarf transition. We place the components of binaries with parallax measurements on nearinfrared color-magnitude diagrams, and compare the results to current absolute magnitude/spectral type trends.

434.15

A Search for Photometric Variability in L and T-type Brown Dwarf Atmospheres.

Harish G. Khandrika¹, A. J. Burgasser¹, B. Swift², C. Melis¹, E. Bowsher¹, B. Sitarski¹ ¹University of California San Diego, ²University of Arizona.

Exhibit Hall

The atmospheres of low-temperature L- and T-type brown dwarfs are cool enough to form clouds of condensates, whose structure has been indirectly studied through rotationally-induced temporal variability. Measurements of the amplitude, timescale and evolution of such variability is necessary to improve upon current one-dimensional atmospheric models, which do not address surface cloud distributions. While a handful of clearly variable late-type dwarfs have been identified in recent years, current sample sizes remain small. Here we present preliminary results from a near-infrared (J and K' band) monitoring program, examining the variability of 8 L and T-type brown dwarfs. Observations were made using the dual-channel Gemini camera at the Lick Observatory 3m telescope. Results from light curves show that two of the targets show signs of variability over integration periods greater than 1.5 hours. Relative photometry of targets with observations at smaller time integrations (0.5-1.0 hours) does not indicate significant fluctuations or variability. Among our sample, 0805+4812, 1416+1348, 1711+2232, 1511+0607, and 0939-2448 were spectral binary candidates, none of which show evidence

of eclipse. We discuss the implications of these results and propose methods to improve brown dwarf monitoring samples.

434.16

The Status of the Resolved Stellar Populations in the Milky Way Globular Clusters using 2MASS Yasna Ordenes¹, P. Pessev²

¹University of La Serena, Chile, ²Gemini Observatory, Chile. Exhibit Hall

We present a comprehensive database of Color-Magnitude Diagrams (CMDs) for all the Milky Way Globular Clusters included in the William Harris catalog. Using the Two Micron All Sky Survey (2MASS) Point Source Catalog (PSC) a JHKs dataset is created for each object. For the clusters with deep CMDs, we present preliminary analysis of the behavior of the theoretical isochrones generated with the Padova Stellar Evolution code in the Near-IR, as a function of age and metallicity. The final objective of the project is to improve our understanding of the resolved stellar populations and the integrated-light properties of the Milky Way globular clusters. As a different application of the database, we present an independent calibration of the TRGB distance indicator in the Near-Infrared.

434.17

Hot, Massive Stars in I Zw 18

Sara R. Heap¹, D. Lindler², E. Malumuth³ ¹NASA's GSFC, ²Sigma Space Corp., ³Wyle Information Systems. Exhibit Hall

I Zw 18 is one of the most primitive blue, compact dwarf galaxies. The ionized gas in I Zw 18 has a low oxygen abundance (O~1/30 Osun) and nitrogen abundance (N~1/100 Nsun) (Pequignot 2008). We have obtained a far-UV spectrum of the northwest massive star cluster of I Zw 18 using Hubble's Cosmic Origins Spectrograph (COS). The spectrum is compatible with continuous star-formation over the past ~10 Myr, and a very low metallicity, log Z/Zsun ~ -1.7, although the stellar surface may be enhanced in carbon. Stellar wind lines are very weak, and the edge velocity of wind lines is very low (~250 km/s).

434.18

A Search for Helium-Core White Dwarfs in Omega Centauri

Suzanne G. Hayward¹, A. M. Cool¹, J. Anderson²

¹San Francisco State Univ., ²Space Telescope Science Institute.

Exhibit Hall

We present initial results of an analysis of the white dwarf sequence in the globular cluster Omega Centauri aimed at testing for the presence of helium-core white dwarfs (He WDs) and identifying potential candidates. He WDs appear redward of the cooling sequence formed by carbon/oxygen white dwarfs; as recently shown in NGC 6397, they can provide a window into critical binary populations in a globular cluster (Strickler et al. 2009). We analyze a 10x10 arcminute mosaic of images we obtained with HST's Advanced Camera for Surveys in F435W (B435), F625W (R625), and F658N filters; it extends out to the half-light radius of the cluster. Using the "effective PSF" photometric technique developed for the WFC by Anderson and King (2006), we construct a B435-R625 vs. R625 color-magnitude diagram (CMD) for ~1.2 million stars in the mosaic. Of the ~570,000 stars that appear in at least three B435 and three R625 images, approximately 3400 lie in the region of the CMD occupied by WDs. Using the three independent measurements in each filter, we compute empirical uncertainties in the B435-R625 colors of the white dwarfs. We then compare these to the measured width of the WD sequence as a function of R to test for the presence of He WDs and identify potential candidates. We compare our results to those of Monelli et al. (2005) and Calamida et al. (2008) who first reported evidence for He WDs in Omega Centauri. This work was supported by NASA grant HST-GO-9442.

The Delta Cephei Infrared Nebula

Massimo Marengo¹, N. R. Evans², P. Barmby³, L. D. Matthews⁴, G. Bono⁵, D. L. Welch⁶, M. Romaniello⁷, D. Huelsman⁸, K. Y. L. Su⁹, G. G. Fazio²

¹Iowa State University, ²Harvard-Smithsonian CfA, ³University of Western Ontario, Canada, ⁴MIT Haystack Observatory, ⁵Universita di Roma Tor Vergata, Italy, ⁶McMaster University, Canada, ⁷European Southern Observatory, Germany, ⁸University of Cincinnati, ⁹University of Arizona. Exhibit Hall

We present the discovery of an infrared nebula around the Cepheid prototype delta Cephei. Large scale (~0.1 pc) nebulosity is detected at 5.8, 8.0, 24 and 70 micron with Spitzer/IRAC and MIPS observations. Surrounding the two stars, the 5.8 and 8.0 micron emission is largely attributable to Polycyclic Aromatic Hydrocarbons (PAHs) swept from the interstellar medium by a wind originating from delta Cephei and its companion. Stochastically heated small dust grains, at least in part condensed in the delta Cephei wind, are the most likely source of the 24 and 70 micron emission. The 70 micron emission, in particular, resembles a bow shock aligned in the direction of the space velocity of delta Cephei with respect to the local interstellar medium. This discovery is the first direct determination of mass loss from a Cepheid star. The mass loss rate is in the range 5×10^{-9} to 6×10^{-8} Mo/yr, which has important implications for the still unsolved "Cepheids mass loss discrepancy" and for the cosmic distance scale as calibrated with the Cepheid period-luminosity relation.

This work is based on observations made with the Spitzer Space Telescope operated by JPL/Caltech under NASA contract. We also acknowledge support from the Chandra X-ray Center, the NSF REU program and the Natural Science and Engineering Research Council of Canada.

434.20

Quantifying Magnetic Stellar Wind Torques

Sean Matt¹, K. B. MacGregor², M. H. Pinsonneault³, T. P. Greene⁴

¹CEA Saclay, France, ²HAO/NCAR, ³Ohio State University, ⁴NASA Ames Research Center. Exhibit Hall

In order to be able to understand the evolution of stellar spin rates and differential rotation, it is necessary to have a rigorous theory for predicting angular momentum loss via magnetic stellar winds that is applicable over a wide range of conditions. Based upon the results of multidimensional, numerical simulations and semi-analytic calculations, we present an improved formulation for predicting the stellar wind torque, which is valid for varying degrees of magnetization in the wind, as well as for stellar spin rates that range from the slow- to the fast-magnetic-rotator regimes.

434.21

A High Resolution Spectroscopic Survey of FUor and EXor Candidates

Joseph P. Liskowsky¹, S. Brittain¹, T. Rettig², E. Gibb³, T. Simon⁴

¹Clemson University, ²University of Notre Dame, ³University of Missouri St. Louis, ⁴University of Hawaii. Exhibit Hall

As part of an ongoing effort to monitor and classify the small group of known young eruptive variables, we present High Resolution Near-Infrared (~2-5 micron) spectra of 4 FUor, EXor and FUor-like sources which show emission and absorption features not necessarily indicative of their presumed classification. This work makes clear that the natures of these objects are not well described by singular classic FUor or EXor accretion models and begins to define a continuum of source types. Specifically, ZCMa, an FUor-like system, as well as PV Cep, an EXor system, show CO absorption at 5 microns but exhibit CO emission at 2 microns, while Brackett gamma is also in emission for both. XZ Tau, a purported EXor, shows Brackett gamma is in emission while the CO at both 2 and 5 microns is in absorption. L1551 IRS 5 shows

absorption for CO at 2 microns, but shows emission at 5 microns. Weak Brackett gamma absorption is detected for this source. Hence, we discuss the implications of using the overtone bandheads of CO as a circumstellar diagnostic.

434.22 Collisional Growth of Planetesimals Andrew B. Shannon¹

¹University of Toronto, Canada.

Exhibit Hall

Large planetesimals grow by accreting smaller bodies in a planetesimal disk. These bodies later become the parent population for producing dusty debris disks. Extrasolar debris disks, with dust luminosities a thousand times brighter than that of our Kuiper belt, and long decay timescales, are inferred to have masses in large planetesimals (>10 km) comparable to the minimum mass solar nebula (MMSN), or, ~10^2 times the present day mass in the Kuiper belt. What leads to such a striking disparity between ours and the extra-solar disks? Past simulations of planetesimal growth have produced large planetesimals with low (< 10%) efficiency, and require MMSN to produce the observed Kuiper belt today. This low efficiency results because accretion is stalled by viscous stirring from the large bodies. This picture changes drastically in the presence of a large mass of cm-sized grains, which collisionally cool themselves.

We use numerical simulations to show that the Cold Classical Kuiper belt can arise from roughly its present day mass (~1% MMSN), and that bright extrasolar debris disks are formed out of much more massive (roughly MMSN) disks.

434.23 Results of the Supernova Classification Challenge Richard Kessler¹

¹University of Chicago.

Exhibit Hall

We report results from the Supernova Photometric Classification Challenge (SNPCC), a publicly released mix of simulated supernovae (SNe), with types (Ia, Ibc, and II) selected in proportion to their expected rate. The simulation was realized in the griz filters of the Dark Energy Survey (DES) with realistic observing conditions (sky noise, point-spread function and atmospheric transparency) based on years of recorded conditions at the DES site. Simulations of non-la type SNe are based on spectroscopically confirmed light curves that include unpublished non-la samples donated from the Carnegie Supernova Project (CSP), the Supernova Legacy Survey (SNLS), and the Sloan Digital Sky Survey-II (SDSS-II). A spectroscopically confirmed subset was provided for training. We challenged scientists to run their classification algorithms and report a type and photo-z for each SN. Participants from 10 groups contributed 13 entries for the sample that included a host-galaxy photo-z for each SN, and 9 entries for the sample that had no redshift information. Several different classification strategies resulted in similar performance, and for all entries the performance was significantly better for the training subset than for the unconfirmed sample. For the spectroscopically unconfirmed subset, the entry with the highest average figure of merit for classifying SNe~Ia has an efficiency of 0.96 and an SN~Ia purity of 0.79. As a public resource for the future development of photometric SN classification and photo-z estimators, we have released updated simulations with improvements based on our experience from the SNPCC, added samples corresponding to the Large Synoptic Survey Telescope (LSST) and the SDSS, and provided the answer keys so that developers can evaluate their own analysis.

Radiative Trasnfer Calculation Of Light Curves And Spectra For Type Ia Sne Models Soma De¹, E. Baron², F. Timmes¹, P. Hauschildt³

¹Arizona State University, ²University of Oklahoma, ³Hamburger Strenwarte, Germany. Exhibit Hall

We present calculations of the light curves and spectra from a suite of Type Ia supernovae models, ranging from standard single degenerate scenarios to double degenerate collisions. We use a fully relativistic and time dependent radiative transfer code PHOENIX for our calculations which is time dependent in both radiative transfer and rate equation. Simple hydrodynamic calculation is used to treat conservation of energy of the gas and the radiation together and also allow different time-scales for gas and radiation. Between two time steps for the calculation of the light curve, the correct distribution of total energy change among gas and radiation is obtained by iteratively solving for the radiative transfer equation and hence the new temperature in the new time step. In our work we explore systematic relationships between the mass of 56ni mass produced, the mass of silicon group elements produced, the white dwarf metallicity, and the mass of unburned material

434.25

The Impact Of Metallicity On The Luminosity Of Type IIP Supernovae

Ricardo A. Covarrubias¹, M. Hamuy², J. J. Dalcanton³

¹*Australian Astronomical Observatory, Australia,* ²*Universidad de Chile, Chile,* ³*University of Washington. Exhibit Hall*

I shall present spectroscopic observations of HII regions in host galaxies of 24 low redshift Type II plateau supernovae (SNe IIP). SNe IIP show a wide range of their observed properties (plateau luminosities, tail luminosities, and expansion velocities) and their physical parameters (explosion energies, ejected masses, initial radii, and 56Ni yields). Using the HII regions emission-line measurements corrected for stellar absorption and extinction, we derive oxygen abundances at the SNe position. When no HII region was possible to observe at the SNe position, we opted to observe bright HII regions located nearby. The oxygen abundances are derived using empirical, theoretical and combined metallicity calibrations summarized on Kewley and Ellison (2008). We compare the optical luminosity of our SNe sample with the abundances measured and performed a Spearman rank correlation

test to the optical luminosity calculated during the plateau phase versus oxygen abundance for all these methods. We find a slight suggestion of a correlation for all the methods, in terms of increasing progenitor luminosity with increasing metallicity. This might be an indication that low luminosity SNe IIP were

born in a lower metallicity environment than those with higher luminosities.

Modeling The Morphology Of SN 1996cr From X-ray Lines At High Resolution

Franz E. Bauer¹, D. Dewey², V. Dwarkadas³

¹Space Science Institute, ²MIT Kavli Institute, ³University of Chicago.

Exhibit Hall

SN1996cr (~3.7 Mpc) was X-ray "dim" up to ~1000 days yet brightened to ~4e39 erg/s (0.5-8 keV) after 10 years (Bauer et al. 2008). A 1-D hydro model of the ejecta-CSM interaction produces good agreement with the measured X-ray light curves and spectra at multiple epochs, suggesting that SN 1996cr was most likely a massive star, M > 30 solar masses, which went from an RSG to a brief W-R phase before exploding within its r ~ 0.04 pc wind-blown shell (Dwarkadas et al. 2010). Further analysis of a 485ks Chandra HETG observation allows velocity-profile fitting to a handful of bright emission lines in the spectrum (e.g., Si and Fe). The line shapes are well fit with axisymmetric emission models that put the higher temperature Fe XXVI emission at high latitudes. The axis orientation is well constrained to be ~55 degrees from our line-of-sight. The latitude variation may be explained either by higher CSM densities near the equator, or by the ejecta having greater velocity along the poles. SN1996cr demonstrates how X-ray emission lines can provide important diagnostics of SN shock structure.

434.27

Spectral Indicators in Type Ia Supernovae and a Possible Link with Reddening

Jakob Nordin¹, L. Östman², A. Goobar¹, M. Sako³, SDSS-II Supernova Survey

¹Stockholm University, Sweden, ²Institut de Fisica dAltes Energies, Spain, ³University of Pennsylvania. Exhibit Hall

We study spectra of Type Ia supernovae (SNe Ia), observed at the NTT and NOT telescopes and obtained in conjunction with the SDSS-II Supernova Survey. This sample is compared with local and SNLS spectra. We explore possible correlations between spectral indicators (pseudo Equivalent Widths and line velocities) and lightcurve parameters, host galaxy properties and redshift.

This analysis is extended to a detailed study of the Si4000 feature, a region showing strong correlations with lightcurve color, spectroscopic (Branch) subtypes and velocity gradient. These results provide further evidence that SNe Ia previously considered as "normal" are intrinsically different, and that the observed reddening of SNe Ia cannot be solely caused by dimming by interstellar dust in the host galaxy. We discuss implications for distance estimates and constraints on cosmological parameters.

434.28

Generalized Semi-Analytical Models Of Type II Supernova Light Curves

Emmanouil Chatzopoulos¹, J. C. Wheeler¹, J. Vinko²

¹University of Texas, Austin, ²University of Szeged, Hungary. Exhibit Hall

We present generalized supernovae (SN) light curve (LC) models for a variety of power inputs including previously proposed mechanisms. We extend those solutions to include non-centrally located power sources and stationary photospheres as might be the case for SN that are powered by ejecta-circumstellar matter (CSM) interaction. To do so we provide an expression for the power input that is produced by a self-similar circumstellar (CS) shock that efficiently converts its kinetic energy into radiation. We find that the CS shock luminosity that we derive is in agreement with results from multi-dimensional radiation hydrodynamics simulations in the case of an optically-thin CSM. We develop a semi-analytical model for the case of an optically-thick CSM by invoking an approximation for the effects of radiative diffusion. We compare fits of our model and LC models for different power inputs introduced by other authors to the observed LCs of the recently-discovered Super Luminous Supernovae (SLSNe) 2005ap, 2006gy, 2006tf, 2007bi, 2008am and 2008es as well as to the strongly interacting SNe

2008iy, PTF09uj and to the peculiar transient SCP06F6. We find that CS shock heating produced by ejecta-CSM interaction provides a better fit to the LCs of most of those events. Some contribution from radioactive decay can improve the fits in some cases. We also address the relation between Type IIL and Type IIn SN with ejecta-CSM interaction models. A faster Type IIL decline can be reproduced by the diffusion of previously deposited shock power if the CS power input to the diffusive component vanishes when the shock breaks out of the optically-thick CSM. We conclude that the observed LC variety of Type IIL, Type IIn and of the SLSNe is likely to be a byproduct of the large range of conditions relevant to significant ejecta-CSM interaction as a power source.

434.29

GALEX and 2MASS Photometry of Underlying Supernova Ia Host Stellar Populations Elsa M. Johnson¹

¹University of Oregon.

Exhibit Hall

We present the broadband FUV-K colors of stellar populations on the physical scale of 1-2 kpc, underlying historical supernovae Ia (SNe Ia) in the nearby Universe. The photometry was performed on GALEX and 2MASS images using 9" diameter apertures centered on regions of both elliptical and spiral galaxies with redshifts of z < 0.01. The colors are compared to the corresponding published B_{max} - V_{max} peak colors of the supernovae in order to determine whether a correlation exists between SN properties and underlying stellar population. A reddening trend is apparent in both faint and bright host stellar populations, such that redder peak SN colors come from redder populations, agreeing with host galaxy extinction estimates from the literature. In order to confirm that this trend is solely dependent on host galaxy dust, we examine the relatively dust-free J-K colors of the same regions. The added benefit of using the J-K color is that it is a strong indicator of metal abundance. We find that stellar populations hosting SNe with colors B_{max} - V_{max} < 0.3 have significantly bluer J-K colors and therefore are metal-poor in comparison to regions that hosted SNe with B_{max} - V_{max} > 0.3. These results suggest that SNe Ia peak colors are a function of their host stellar population metallicity and that many disk SNe Ia occur in regions of moderate reddening.

434.30

Evidence for Circumstellar Material in Type Ia Supernovae via Na I D Absorption Features

Assaf Sternberg¹, A. Gal-Yam¹, J. D. Simon², D. C. Leonard³, R. M. Quimby⁴, M. M. Phillips⁵, N. I. Morell⁵, G. W. Preston², I. B. Thompson², I. I. Ivans⁶, J. L. Marshall⁷, A. V. Filippenko⁸, G. W. Marcy⁸, J. S. Bloom⁸, F. Patat⁹, D. Yong¹⁰, B. E. Penprase¹¹, I. Toro Martinez¹¹, D. J. Beeler¹¹, J. C. Wheeler¹², C. Allende Prieto¹³, G. S. Stringfellow¹⁴

¹Weizmann Institute of Science, Israel, ²Observatories of the Carnegie Institution of Washington, ³San Diego State University, ⁴California Institute of Technology, ⁵Carnegie Observatories, Las Campanas Observatory, Chile, ⁶University of Utah, ⁷Texas A&M University, ⁸University of California, Berkeley, ⁹Euroean Southern Observatory, Germany, ¹⁰The Australian National University, Mount Stromlo Observatory, Australia, ¹¹Pomona College, ¹²The University of Texas at Austin, ¹³Universidad de La Laguna, Institutio de Astrofísica, Spain, ¹⁴University of Colorado. Exhibit Hall

Type Ia Supernovae (SNe Ia) have high and homogeneous luminosities, making them an essential tool for measuring distances on a cosmic scale, useful to gauge the geometry and evolution of the Universe. However, the nature of the progenitor system of these explosions is still uncertain. The consensus view is that SNe Ia originate from an accreting carbon-oxygen white dwarf (WD) in a binary system, that undergoes a thermonuclear explosion as its mass approaches the critical Chandrasekhar limit. In the single degenerate (SD) model the mass donor is either a main sequence or an evolved star, while the

double degenerate (DD) model involves a second WD as the mass donor. In the SD model non-accreted material blown away from the system prior to the explosion would remain as circumstellar material (CSM). Detection of such material in SN Ia spectra would support the SD model. Recently, claims for such detections were reported for four SN Ia events (SN2006X, SN2007le, SN 1999cl and SN2006dd), manifest as time variable Na I D absorption features. We report the analysis of the largest high resolution SN Ia spectra sample to date, consisting of 35 SN Ia events, obtained using the Keck HIRES and Magellan MIKE spectrographs. 22 of these events exhibit significant Na I D absorption. We report a statistical preference for blue-shifted absorption structures (similar to those seen in SN 2006X and SN 2007le) that is incompatible with observations of the Milky way absorption systems or an additional core collapse SN sample. This apparent asymmetry suggests that most of these features are intrinsic to the SNe themselves, supporting the SD model for the progenitor system of a large fraction of SNe Ia in nearby (z&It;0.06) spiral and lenticular galaxies.

434.31

Ejecta Knot Evolution in Cas A

John Rutherford¹, E. Figueroa-Feliciano¹, D. Dewey¹, S. Trowbridge¹, F. Bastien², K. Sato¹

¹MIT, ²Vanderbilt University.

Exhibit Hall

Supernova remnants are remarkable laboratories for studying, among other phenomena, explosive nucleosynthesis and plasma dynamics. Time-dependent signatures of such processes can further inform our understanding, and may be found in widely spaced epochs of observation from high spatial and spectral resolution instruments.

We investigated the spectral evolution in the X-ray band of the bright ejecta knots in Cassiopeia A over the last decade. Both dispersed and non-dispersed spectra from the Chandra HETG and ACIS instruments were used for this study, helping to better constrain signs of evolution. We present our findings of how such physical properties as the temperature, elemental abundances, velocity, and nonequilibrium ionization age changed over ten years of the several hundred year old remnant's lifetime, along with a careful analysis of the confounding background contamination and model parameter correlations.

434.32

21cm Absorption Line Zeeman Observations And Modeling Of Physical Conditions In M16

Furea Kiuchi¹, C. Brogan², T. Troland¹ ¹University of Kentucky, ²NRAO.

Exhibit Hall

We present detailed 21 cm HI absorption line observations of M16 using the Very Large Array. The M16 "pillars of creation" are classic examples of the interaction of ISM with radiation from young, hot stars. Magnetic fields can affect these interactions, the 21 cm Zeeman effect reveals magnetic field strengths in the Photodissociation regions associated with the pillars. The present results yield a 3-sigma upper limit upon the line-of-sight magnetic field of about 300 microgauss. This limit is consistent with a total field strength of 500 microgauss, required in the molecular gas if magnetic energies and turbulent energies in the pillars are in equipartition. Most likely, magnetic fields do not play a dominant role in the dynamics of the M16 pillars. Another goal of this study is to determine the distribution of cold HI in the M16 region and to model the physical conditions in the neutral gas in the pillars. We used the spectral synthesis code Cloudy 08.00 for this purpose. We adopted the results of a published Cloudy HII region model and extended this model into the neutral gas to derive physical conditions therein.

Radio Recombination Lines Toward W51A

Emy M. Rivera¹, M. Lebrón¹, H. Arce², C. Salter³, T. Ghosh³, R. Minchin³ ¹University of Puerto Rico, ²Yale University, ³Arecibo Observatory. Exhibit Hall

For the first time radio recombination lines at 800MHz have been detected toward W51A. The spectra are analyzed and compared with lines at higher frequencies. The line width of the H α 210 and H α 206 are 25 and 31 km/s, respectively. There is no signature of pressure broadening as expected from the radio recombination line theory. From the literature, the radio continuum at 800Mhz on W51A is expected to be optically thick.

434.34

Comparisons Of The Interstellar Magnetic Field Directions Obtained From The Ibex Ribbon And Interstellar Polarizations

Priscilla C. Frisch¹, B. Andersson², A. Berdyugin³, H. Funsten⁴, M. Magalhaes⁵, D. McComas⁶, V. Piirola³, N. Schwadron⁷, J. Slavin⁸, S. Wiktorowicz⁹

¹Univ. of Chicago, ²SOFIA/USRA, ³Univ. of Turku, Finland, ⁴Los Alamos National Lab, ⁵Univ. Sao Paulo, Brazil, ⁶SWRI, ⁷Univ. New Hampshire, ⁸Harvard-Smithsonian Center for Astrophsics, ⁹Univ. of California. Exhibit Hall

Variations in the spatial configuration of the interstellar magnetic field (ISMF) near the Sun are constrained by the ISMF direction determined by the Interstellar Boundary Explorer spacecraft (IBEX) observations of a 'Ribbon' of energetic neutral atoms (ENAs). The Ribbon is observed for sightlines perpendicular to the ISMF as it drapes over the heliosphere. The center of the Ribbon arc is compared with the ISMF direction derived from optical polarization data for stars within ~40 pc. These comparisons are based on old and new interstellar polarization data for ~30 nearby stars within 90 deg of the heliosphere nose, and utilize a fitting process to determine the ISMF direction from the polarization position angles. This research is supported by NASA funding, and by NASA funding of the IBEX mission, as a part of NASA's Explorer Program.

434.35

Physical Conditions of the Small Magellanic Cloud HII Region NGC 456 and the Underestimated Heavy Element Abundances of the Universe

Maria Angeles Pena-Guerrero¹, A. Peimbert¹

¹IA - UNAM, Mexico.

Exhibit Hall

We study the O/H abundance determinations in HII regions in the presence of temperature inhomogeneities (as proposed by Peimbert in 1967), t^2 . The first object of our study is NGC 456, which the second brightest HII region of the Small Magellanic Clouds (SMC); we find it has an abundance 1.75 times higher than previously determined. Traditionally it is assumed that these objects have the same temperature throughout the whole volume; this temperature is then used to calculate abundances. Our determination was done using Collisionally Excited Lines (CEL) and the t^2 obtained from HeI lines; it is consistent with abundances determined with Recombination Lines (RL). The most well known strongline ratio or metallicity indicator used to determine the O/H ratio is $O_{23} = ([OII]3727\text{Å} + [OIII]4959,5007\text{Å})$ / H β introduced by Pagel *et al.* (1979). The log(O_{23}) *vs.* 12+log(O/H) diagram constitutes an important tool in the study of objects with low intrinsecal brightness or high redshift. To account for the presence of thermal inhomogeneities, the upper branch of the O_{23} -O/H diagram can be recalibrated using RLs whereas in the lower branch of the diagram RLs cannot be used due to their faintness. For low metallicity objects the formalism of t^2 is applied to CELs to determine abundances and recalibrate the O_{23} -O/H diagram.

We find that the point corresponding to NGC 456 in the diagram shifts up by 0.24 dex in the 12+log(O/H) axis. This is consistent with preliminary results for the next 3 objects of our sample and with the behavior of other HII regions from the literature were t^2 has been measured. The systematic shift in the curve of the O₂₃-O/H diagram implies that abundances in the Universe need to be corrected by a factor of approximately 2.

434.36

Molecular Cloud Evolution IV. Magnetic Fields and Ambipolar Diffusion

Enrique Vazquez-Semadeni¹, G. Gomez¹, R. Banerjee², P. Hennebelle³, D. Duffin⁴ ¹*CRyA-UNAM, Mexico,* ²*ITA, Germany,* ³*ENS, France,* ⁴*McMaster, Canada. Exhibit Hall*

We investigate the formation and evolution of giant molecular clouds (GMCs) by the collision of convergent warm neutral medium (WNM) streams in the interstellar medium, in the presence of magnetic fields and ambipolar diffusion (AD), focusing on the evolution of the star formation rate (SFR) and efficiency (SFE), as well as of the mass-to-magnetic-flux ratio (M2FR) in the forming clouds. Our main results are: 1) A suite of simulations with global M2FRs 1.4, 0.9 and 0.7 spans a continuum of SFEs ranging from ~ 35% to ~ 3%. 2) The moderately subcritical run with M2FR=0.7 entirely shuts off its star formation activity after ~ 4 Myr. 3) The fragmentation of the cloud by the combined action of thermal, gravitational, and nonlinear thin-shell instabilities produces dense clumps of high M2FR and low density patches of low M2FR. Thus, the M2FR is a highly fluctuating function of position, with the 3-sigma range spanning over one and a half dex in the M2FR. 4) We report the occurrence of an unexpected phenomenon of buoyancy of the low-M2FR regions within the gravitationally-contracting clouds.

434.37

The Mass Of H2 In The Envelope Of MBM40.

David L. Cotten¹, L. Magnani¹, E. Wennerstrom¹, J. Onello² ¹University of Georgia, ²State University of New York. Exhibit Hall

We used OH 18 cm observations from the GBT and the E(B-V) map from Schegel, Finkbeiner, & amp; Davis (1998) to obtain the molecular mass of the envelope of the translucent molecular cloud, MBM40. We detected OH emission in regions with E(B-V) as low as 0.12 magnitudes and determined from the dust maps that the molecular mass in the envelope of the cloud is approximately 10 solar masses. This is comparable to the mass along the previously-mapped dense regions of the cloud (E(B-V) & gt; 0.2 magnitudes). The OH 18 cm lines are an excellent tracer of the low-density, low-extinction regions in translucent molecular clouds. A portion of this research was supported by an NRAO Student Observing Support Award.

Radio Observations And Interstellar Magnetic Fields Characteristics: The Power Spectrum And Magnetic Helicity

Antonina Volegova¹, R. Stepanov¹

¹Institute of Continuous Media Mechanics, Russian Federation.

Exhibit Hall

We study possible relationships between turbulent magnetic field properties and radio emission statistics using numerical models of the ISM with variable helical and spectral characteristics of magnetic fields. We discuss how spectral analysis of the total and polarized intensity maps can be used to estimate the power spectrum of the magnetic field. We present a new solution which connects magnetic helicity and correlation between Faraday rotation measure and polarization degree of radio synchrotron emission. Effects of depolarization play the main role in this problem and allow us to detect magnetic helicity for certain frequency band of observable radio emission.

434.39

Magneto-hydrodynamic Simulations of Parker Instability Undergoing Cosmic-Ray Diffusion Chih-Yueh Wang¹, Y. Lo¹

¹Chung-Yuan Christian University, Taiwan.

Exhibit Hall

Parker instability arises from the presence of magnetic fields in a plasma such as the interstellar medium (ISM), wherein the magnetic buoyant pressure expels the gas and causes the gas to move along the field lines. The subsequent gravitational collapse of the plasma gas is thought to be responsible for the formation of giant molecular clouds in the Galaxy. The process of clump formation in the ISM near the Galactic plane is investigated. The initial ISM is assumed to consist of two fluids: plasma gas and cosmic-ray particles, in hydrostatic equilibrium, coupled with a uniform, azimuthally-aligned magnetic field. The evolution of the instability is explored in two models: an isothermal exponential-declining density model and a two-layered, hyperbolic tangent temperature model. After a small perturbation, the unstable gas aggregates at the bottom of the magnetic loops and forms dense blobs. The growth rate of the instability decreases as the coupling between the cosmic rays and the plasma becomes stronger (meaning a smaller CR diffusion coefficient). The mixing is enhanced by the cosmic-ray diffusion, while the shape of the condensed gas depends sensitively on the initial equilibrium conditions. In the hyperbolic tangent temperature model, a more concentrated and round shape of clumps like the giant molecular cloud is observed at the foot points of rising magnetic arches. Conversely, in the exponential density model, a filamentary morphology of the clumpy structure is attained.

434.40

Anomalous Abundances in Gaseous Nebulae From Recombination and Collisional Lines: Improved Photoionization and Recombination Studies

Anil Kumar Pradhan¹, S. N. Nahar¹, W. B. Eissner², M. Montenegro³

¹Ohio State Univ., ²University of Stuttgart, Germany, ³Universidad Catholica de Chile, Chile. Exhibit Hall

A perplexing anomaly arises in the determination of abundances of common elements in gaseous nebulae, as derived from collisionally excited lines (CEL) as opposed to those from Recombination Lines (RCL). The "abundance discrepancy factors" can range from a factor of 2 to an order of magnitude or more. That has led to quite different interpretation of the physical structure and processes in gaseous nebulae, such as temperature fluctuations across the object, or metal-rich concentrations leading to a dual-abundnace scenario.

We show that the problem may lie in inaccuracies in photoionization and recombination models

neglecting low-energy resonance phenomena due to fine structure. Whereas the atomic physics of electron impact excitation of forbidden lines is well understood, and accurate collision strengths have long been available, that is not generally the case for electron-ion recombination cross sections. A major problem is the inclusion of relativisitic effects as it pertains to the existence of very low-energy fine structure resonances in photoionization cross sections. We carry out new relativistic calculations for photoionization and recombination cross sections using a recently extended version of the Breit-Pauli R-matrix codes, and the unified electron-ion recombination method that subsumes both the radiative and the dielectronic recombination (RR and DR) processes in an ab initio and self-consistent manner. We find that near-thresold resonances manifest themselves within fine structure levels of the ground state of ions, enhancing low-temperature recombination rate coefficients at ~1000-10,000 K. The resulting enahncement in level-specific and total recombination rate coefficients should therefore lead to reduced abundances derived from RCL, and in accordance with those from CEL.

We present results for photoionization of O II into, and recombination from, O III. Theoretical cross sections are benchmarked against high-resolution measurements from synchrotron based light sources. Work on other atomic species is in progress.

434.41

The Search for Interstellar Sulfide Grains

Lindsay P. Keller¹, S. Messenger¹

¹NASA Johnson Space Center.

Exhibit Hall

The lifecycle of sulfur in the galaxy is poorly understood. Fe-sulfide grains are abundant in early solar system materials (e.g. meteorites and comets) and S is highly depleted from the gas phase in cold, dense molecular cloud environments. In stark contrast, S is essentially undepleted from the gas phase in the diffuse interstellar medium, indicating that little S is incorporated into solid grains in this environment. It is widely believed that S is not a significant component of interstellar dust grains. This is a rather puzzling observation unless Fe-sulfides are not produced in significant quantities in stellar outflows, or their lifetime in the ISM is very short due to rapid destruction.

Fe sulfide grains are ubiquitous in cometary samples where they are the dominant host of S. The Fesulfides (primarily pyrrhotite; $Fe_{1-x}S$) are common, both as discrete 0.5-10 µm-sized grains and as fine (5-10 nm) nanophase inclusions within amorphous silicate grains. Cometary dust particles contain high abundances (~1000 ppm) of well-preserved presolar silicates and organic matter and we have suggested that they should contain presolar sulfides as well. This hypothesis is supported by the observation of abundant Fe-sulfides grains in dust around pre- and post-main sequence stars inferred from astronomical spectra showing a broad 23 µm IR feature due to FeS. Fe-sulfide grains also occur as inclusions in *bona fide* circumstellar amorphous silicate grains. Our irradiation experiments show that FeS is far more resistant to radiation damage than silicates. Consequently, we expect that circumstellar Fe sulfide grains should be as abundant as circumstellar silicate grains in solar system materials.

434.42

Measuring Reddening with SDSS Stellar Spectra

Eddie Schlafly¹, D. P. Finkbeiner²

¹Harvard, ²Harvard/CfA.

Exhibit Hall

We present measurements of dust reddening using the colors of stars with spectra in the Sloan Digital Sky Survey. We measure reddening as the difference between the measured colors of a star and the predicted colors, as derived from stellar parameters from the SEGUE Stellar Parameter Pipeline. We achieve uncertainties of 54, 34, 25, and 28 mmag in the colors u - g, g - r, r - i, and i - z, per star, though

the uncertainty varies depending on the stellar type and the magnitude of the star. The spectrum-based reddening measurements confirm our earlier "blue tip" reddening measurements, preferring an $R_v = 3.1$ Fitzpatrick (1999) reddening law to O'Donnell (1994) or Cardelli et al. (1989) reddening laws. We obtain a reddening law normalization within 4% of the blue tip results, despite the somewhat different sky footprint used in the two analyses.

434.43

The Star Formation Rate and Gas Surface Density Relation in the Milky Way: Implications for Extragalactic Studies

Amanda L. Heiderman¹, N. J. Evans, II¹, L. E. Allen², T. Huard³, M. Heyer⁴

¹University of Texas at Austin, ²National Optical Astronomy Observatory, ³University of Maryland, ⁴University of Massachusetts.

Exhibit Hall

We investigate the relation between star formation rate (SFR) and gas surface densities in Galactic star forming regions using a sample of YSOs and massive clumps. Our YSO sample consists of objects located in 20 molecular clouds from the Spitzer c2d and Gould's Belt surveys. We estimate the gas surface density (Sigma gas) from Av maps and YSO SFR surface densities (Sigma SFR) from the number of YSOs, assuming a mean mass and lifetime. We also divide the clouds into contour levels of Av, counting only the youngest Class I and Flat SED YSOs. For a sample of massive star forming clumps, we derive SFRs from the infrared luminosity and use HCN gas maps to estimate Sigma gas. We find that Galactic clouds lie above the extragalactic relations (e.g., Kennicutt-Schmidt Law) by factors up to 17. Cloud regions with high Sigma gas lie above extragalactic relations up to a factor of 54 and overlap with massive clumps. We use 12CO and 13CO gas maps of the Perseus and Ophiuchus clouds to estimate Sigma gas and compare to Sigma_gas from Av maps. We find that 13CO, underestimates the Av-based mass by factors of 4-5. 12CO may underestimate the total gas mass at Sigma gas > 200 Msun pc^-2 by > 30%; however, this does not explain the large discrepancy between Galactic and extragalactic relations. We find evidence for a threshold of star formation (Sigma th) at 129+-14 Msun pc^-2. At Sigma gas > Sigma th, the Galactic relation is linear. A possible reason for the difference between Galactic and extragalactic relations is that all the CO-emitting gas, including Sigma gas below Sigma th, is measured in extragalactic studies. If the Kennicutt-Schmidt relation (Sigma SFR~Sigma gas^1.4) and a linear relation between dense gas and star formation is assumed, the fraction of dense gas (f dense) increases as Sigma gas^0.4. When Sigma gas reaches ~300Sigma th, f dense is 1.

434.44

Discovery Of An Expanding Molecular Bubble In Orion BN/KL

Laurent Loinard¹, L. A. Zapata¹, L. F. Rodriguez¹, J. Schmid-Burgk², P. Ho³, N. Patel⁴ ¹UNAM, Mexico, ²MPIfR, Germany, ³ASIAA, Taiwan, ⁴CfA. Exhibit Hall

During their infancy, stars are well known to expel matter violently in the form of well-defined, collimated outflows. A fairly unique exception is found in the Orion BN/KL star-forming region where a poorly collimated and somewhat disordered outflow composed of numerous elongated ``finger-like'' structures was discovered more than 30 years ago. In this talk, we report the discovery in the same region of an even more atypical outflow phenomenon. Using \$^{13}\$CO(2-1) line observations made with the Submillimeter Array (SMA), we have identified there a 500 to 1,000 years old, expanding, roughly spherically symmetric bubble whose characteristics are entirely different from those of known outflows associated with young stellar objects. The center of the bubble coincides with the initial position of a now defunct massive multiple stellar system suspected to have disintegrated 500 years ago, and with the center of symmetry of the system of molecular fingers surrounding the Kleinmann-

Low nebula. We hypothesize that the bubble is made up of gas and dust that used to be part of the circumstellar material associated with the decayed multiple system. The Orion hot core, recently proposed to be the result of the impact of a shock wave onto a massive dense core, is located toward the south-east quadrant of the bubble. The supersonic expansion of the bubble, and/or the impact of some low-velocity filaments provide a natural explanation for its origin.

434.45

Young Stellar Object Variability as a Probe of Circumstellar Structure

Kevin M. Flaherty¹, J. Muzerolle², G. Rieke¹

¹University of Arizona, ²STSCI.

Exhibit Hall

The Spitzer space telescope, with its sensitivity and efficient mapping capabilities, has opened up the field of infrared variability, which was previously restricted to detailed studies of individual stars over a limited wavelength range. My thesis at the University of Arizona is a combination of observations and modeling of young stellar object variability. In the young cluster IC 348, one of the transition disks, LRLL 31, displays mid-infrared variability in which the 5-8micron flux decreases while the 8-40micron flux increases in observations separated by only seven days. I have developed simple radiative transfer models that can explain the wavelength dependence and size of this variability based on a warp at the inner edge of the disk with variable scale height. In order to more directly probe the hot dust emission, I obtained repeated 3.6 and 4.5micron photometry of IC 348 over the course of 35 days, supported by ground-based 0.8-5micron spectra of select transition disk variables. Roughly 70% of the stars with an infrared excess for LRLL 31 that has never been seen before. These multi-wavelength multi-epoch observations help to restrict the possible models available for explaining mid-infrared variability in young stellar objects, and hint at the possibility of using variability as a method for studying inner disk structure.

434.46

The Distance to the Ophiucus Stellar Formation Region

Sergio A. Dzib¹, L. Loinard², A. J. Mioduszewski³, M. Claussen³, L. F. Rodriguez², R. M. Torres⁴ ¹*CRyA-UNAM and NRAO, Mexico,* ²*CRyA-UNAM, Mexico,* ³*NRAO,* ⁴*MPIfR, Germany. Exhibit Hall*

The distance to the Ophiuchus stellar formation region has been a controversial subject in the recent years. High resolution VLBA observations of young stellar objects gived a distance of ~120 pc. On the other hand, high resolution VERA observations of water maser related with the young stellar object IRAS 16293-2422 gived a distance of ~180 pc. The two explanation that conciliate both results are: (i) an elongated structure of 60 pc and (ii) that two different stellar fomation regions are in the same line of sight. However, both explanations seems to be unlikely. For a better study of this issue we take VLBA archive data of 17 observations of water masers, related with the young stellar objects IRAS 16293-2422 and YLW16A. Here, we discuss the results.

S.D. acknowledge the financial support of UNAM and NRAO. NRAO is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

434.47 Mass Accretion Rates of Herbig Ae/Be Stars. Brian Donehew¹, S. Brittain¹

¹Clemson Univ.. Exhibit Hall

We present Brackett-gamma and Balmer Discontinuity observations of a large sample of Herbig Ae/Be candidate stars. Herbig Ae/Be stars are the higher mass analogues of T Tauri stars, and both are young stellar objects accreting material from a circumstellar disk. We determine the mass accretion rates of the stars in our sample by measuring the veiling of the Balmer Discontinuity due to accretion. In T Tauri stars, there is a well established correlation between Brackett-gamma luminosity and mass accretion luminosity, and thus mass accretion rate. We determine if this correlation holds true for Herbig Ae/Be stars, and over what spectral range.

434.48

Detailed Chemical Abundances in the Unusual Globular Cluster Palomar 1

Charli Sakari¹, K. Venn¹, N. Arimoto², W. Aoki², M. Irwin³

¹University of Victoria, Canada, ²National Astronomical Observatory of Japan, Japan, ³Institute of Astronomy, University of Cambridge, United Kingdom.

Exhibit Hall

Detailed chemical abundances for twenty one elements are presented for four red giants in the anomalous globular cluster Palomar 1 using high-resolution (R=36000) spectra from the High Dispersion Spectrograph (HDS) on the Subaru telescope. Pal 1 has long been considered unusual because of its low surface brightness, sparse red giant branch, young age, and its possible association with an extragalactic stream of stars. The mean metallicity of the four stars is in agreement with the Ca II triplet metallicity, [Fe/H] = -0.6 + -0.2, and does not show significant scatter from star to star. Furthermore, the [alpha/Fe] ratios are similar to those of Galactic stars at this metallicity; therefore the chemistry of these 4 stars suggests that Pal 1 does not have an (obvious) extra galactic origin. However, some variations in the heavy element abundances do indicate an interesting formation/evolutionary history for this cluster.

434.49

CN and CH Abundance Analysis in a Sample of Eight Galactic Globular Clusters

Jason P. Smolinski¹, Y. Lee¹, T. C. Beers¹, S. L. Martell², D. An³, T. Sivarani⁴ ¹*Michigan State University/JINA*, ²*ARI*, *Universitaet Heidelberg, Germany*, ³*Ewah Womans University*, *Korea, Republic of*, ⁴*IIAA*, *India*.

Exhibit Hall

Galactic globular clusters exhibit star-to-star variations in their light element abundances that are not predicted by formation and evolution models involving single stellar generations. Recently it has been suggested that internal pollution from early supernovae and AGB winds may have played important roles in forming a second generation of enriched stars. We present updated results of a CN and CH abundance analysis of stars from the base to the tip of the red giant branch, and in some cases down onto the main sequence, for eight globular clusters with available photometric and spectroscopic data from SDSS-I and SDSS-II/SEGUE. These results include a discussion of the radial distribution of CN enrichment and how this may impact the current paradigm. Funding for SDSS-I and SDSS-II has been provided by the Alfred P. Sloan Foundation, the Participating Institutions, the National Science Foundation, the U.S. Department of Energy, the National Aeronautics and Space Administration, the Japanese Monbukagakusho, the Max Planck Society, and the Higher Education Funding Council for England. The SDSS Web Site is http://www.sdss.org/.

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Astrophysics (JINA), awarded by the U.S. National Science Foundation.

434.50

Bulk Velocities and Orbits of Open Clusters

Peter M. Frinchaboy¹, D. Chojnowski¹

¹Texas Christian Univ. (TCU).

Exhibit Hall

We present bulk 3D dynamics for 10+ northern hemisphere open clusters. Utilizing WIYN/Hydra multifiber spectroscopic observations and Tycho and/or UCAC-3 proper motions, we determine cluster membership and bulk velocities. Cluster velocities are used to derive cluster orbits with comparison to previous studies.

This work was partially supported by an NSF Astronomy and Astrophysics Postdoctoral Fellowship under award AST-0602221 and by a TCU SERC grant

434.51

Circumstellar Disk Studies In The Near-ir With Mmt-ao And Clio2 Katherine B. Follette¹

¹University of Arizona.

Exhibit Hall

We present a pilot study of near infrared scattered light imaging of circumstellar disks, which allows us to probe the presence of water ice. Its existence is revealed by a deficit at the 3.09µm spectral feature relative to the continuum. Using the MMT-AO system and Clio2 camera, we are able to image such disks from ~0.1" outward without the use of a coronagraph. We are further able to estimate the average grain size in the outer disk through NIR colors. Having succeeded in a proof of concept study of the GM Aur transitional disk, we aim to expand our study to include an array of circumstellar disks around premain sequence stars of a variety of spectral types in order to probe grain properties and dust evolution.

434.52

Overabundance of Short-Period Variables among Solar-type Stars?

Cassie Reuter¹, N. Carroll², J. Zierten², G. B. Hughes³, P. Lubin²

¹UC Berkeley, ²UC Santa Barbara, ³Cal Poly, FLIR.

Exhibit Hall

The Kepler mission is designed to photometrically detect extrasolar planetary transits. In addition to providing opportunities for exoplanet detection, the light curves gathered by Kepler also contain unprecedented information on stellar variability. Many of the stars surveyed by the mission are solar mass or smaller and a potentially surprising fraction of these exhibit clear periodic behavior on timescales between 0.5-5 days. One interpretation is that more of these type G and cooler stars are rotating more rapidly than expected, which might imply more very young stars than expected. There are other potential explanations for the periodicity that could mimic rotation of young stars. Among these are close (sometimes eclipsing) binaries, harmonics of the rotation period, or stellar pulsation. We examine the statistics of the short period systems, and evaluate the sources of the short-period signals.

435 *The Solar System II* Poster Session *Exhibit Hall*

435.01

An Analysis of Silicate Hiding in Saturn's Rings: Dependence on Surface Density Crosby Burdon¹, M. C. Lewis¹

¹*Trinity University.*

Exhibit Hall

Among the curious optical properties of Satun's rings, one is the fact that they appear to be composed of primarily water ice with very few contaminants. This work is aimed at determining if the rings are capable of hiding other material (namely silicates) in such a way that it does not appear in the spectrometry of the rings. Our research was focused on finding patterns in the amount of silicates visible for a variable percent total particle silicate mix (0.5-4%) and surface density (40 and 60 g/cm^2 respectively). This was accomplished using N- body spherical particle simulations that model interactions between ring particles. These simulations were then input into a data analysis program designed called SwiftVis, which also allowed ray tracing of incoming photons to give us an idea of what we would see. Our results indicate thus far that the surface density of the rings (which varies between the different sections of the rings) has the largest contribution to variation in optical structure. Quantitatively determining whether a silicate particle is visible simply requires knowledge of the last particle to reflect light back to the camera. For a 40 g/cm^2 ring system, the amount of silicates that show up in the photometry is about 25% of the original percentage (i.e for a 1% total fraction the amount of silicates visible single single calles vary widely from ring to ring as the surface density changes.

435.02

The Pan-STARRS-1 Outer Solar System Pipeline

Matthew J. Holman¹, P. Protopapas¹, Y. Chen², H. Lin², T. Grav³, D. Ragozzine¹, Pan-STARRS-1 Science Consortium

¹Harvard-Smithsonian, CfA, ²National Central University, Taiwan, ³Johns Hopkins University. Exhibit Hall

The Pan-STARRS-1 survey began full scale scientific operation in May, 2010. Roughly 60% of the observing time of the Pan-STARR-1 telescope is dedicated to a "3pi steradian" survey with an observing cadence that is suitable for the detection of near-Earth asteroids and slow-moving solar system bodies. Over this course of its science mission, Pan-STARRS-1 survey will discover a large number of asteroids, Trojans, Centaurs, comets, and trans-neptunian objects (TNOs) brighter than the limiting magnitude of the survey (r=22 to r=22.5). This census will be used to address a large number of questions regarding the physical and dynamical properties of the various small body populations of the solar system. In addition, this survey will determine the population of large, distant, and rare members of the outer solar system and have the potential to detect planet-sized objects at great distances.

We have developed an independent software pipeline that is optimized for the detection of outer solar system bodies at and beyond the distance of Jupiter. This pipeline is efficient, flexible, and portable. It is suitable for use in future wide-field surveys such as LSST. We have recently demonstrated the successful operation of this pipeline with the discovery of new TNOs and the recovery of TNOs found by previous surveys. We present the details of the software pipeline.

In addition, we present details of the outer solar system objects discovered and recovered by Pan-STARRS-1 to date, including follow-up observations.

Cassini VIMS Measurements of Titan's Surface Albedo; Preliminary Results.

Turner Jake¹, C. A. Griffith¹, L. Doose¹, P. Penteado²

¹University of Arizona, ²University of Sao Paulo, Brazil.

Exhibit Hall

One of the main scientific objectives of the Cassini mission is to determine the surface composition and its distribution on Titan. Towards this objective, the Cassini spacecraft possesses an instrument called the Visual and Infrared Mapping Spectrometer (VIMS), which is designed to measure reflected and emitted UV to near-IR spectra from the atmospheres and surfaces of Saturn and its moons. We use a discrete ordinates radiative transfer model of Titan's atmosphere that can separately determine the surface albedo and scattering characteristics of the atmosphere. The scattering characteristics of the tropical atmosphere were derived from the Descent Imager-Spectral Radiometer (DISR) onboard the Huygens probe during its decent. We limited our study to the tropical region of Titan. The albedo of Titan's surface can only be determined through atmospheric windows that peer through Titan's thick atmosphere. For this reason we are able to determine only the albedo at 1.08 microns, 1.28 microns, and 1.58 microns. Knowledge of the albedo of Titan's surface is a crucial step in determining the composition of the surface. We present here preliminary results of several regions near the Huygens landing site on Titan where the surface albedo has been accurately determined.

435.04

The Formation of Double-Lobed Comets and Asteroids through Rotational Reshaping Mark ${\sf Hammergren}^1$

¹Adler Planetarium.

Exhibit Hall

Recent imaging of the nucleus of Comet Hartley 2 by the Deep Impact (EPOXI) spacecraft revealed a strongly bilobate or peanut-shaped object, reminiscent in general form of several other asteroids and comet nuclei that have been resolved by spacecraft and radar observations. In this work, I use a guasistatic shape deformation model simulating mass wasting (landslides) as a process by which small bodies may be globally reshaped. Such landslides may be caused when variations in the object's rotation rate lead to local slopes exceeding the angle of repose. Increases in rotation rate can cause material to migrate away from the rotation axis, perhaps even leaving the surface. Decreases in rotation rate may cause elongated asteroids to collapse back toward the center of mass, resulting in the apparently common double-lobed peanut shapes. This model predicts that the occurrence of such shapes is dependent on the relative strength and frequency of mechanisms that alter the rotation rate of small bodies. Active (or formerly active) comets, with their jets of volatiles, will probably be most strongly affected by changes in rotation rate and thus may be the most likely objects to display peanut shapes. Small asteroids and inactive comets, which are subject to the YORP effect, may be the next most common, particularly those planet-crossing asteroids which also experience planetary tidal forces. Large main belt asteroids, which have their rotations changed mainly by off-center impacts, will probably be least likely to have double-lobed shapes.

435.05

Coma and Disk Modeling using Coupled Escape Probability Alan Gersch¹, M. F. A'Hearn¹ ¹Univ. of Maryland. *Exhibit Hall* In order to better understand the innermost regions of cometary comae, such as those observed with high spatial resolution in the Deep Impact and EPOXI missions, we have built a radiative transfer model for optically thick molecular emission spectra.

We use Coupled Escape Probability, a new accurate method of radiative transfer, which we have improved to be used in an asymmetric spherical situation.

Our model can also be of use in other applications and/or geometries, such as, for example, in protoplanetary disks.

Four species/molecules have been modeled thus far: CO, CO2, H2O and SiO.

The first three are particularly relevant for Deep Impact/EPOXI observations of Tempel 1 and Hartley 2, as well as other cometary spectra. SiO is for use in protoplanetary disk studies.

435.06

Simulating the Performance of the Whipple Space Survey of the Outer Solar System Pavlos Protopapas¹, C. Alcock¹

¹Harvard.

Exhibit Hall

Whipple is a proposed Discovery-class mission that will explore the outer Solar System be searching for serendipitous occultations of stars by small bodies. Whipple will test fundamental predictions of the theories of the origin and evolution of the solar system by studying directly the populations of small objects that lie beyond the orbit of Neptune, including the Kuiper Belt and scattered disk, the region surrounding Sedna, and the Oort Cloud.

Whipple will employ a Schmidt-Cassegrain optical design with a 77 cm aperture, imaging onto a focal plane of 37 square degrees. The focal plane will comprise nine CMOS devices that can produce high signal-to-noise photometric light curves for stars at a variety of cadences: 10,000 stars at 40 Hz, 20,000 stars at 20 Hz, or 40,000 stars at 10 Hz.

We have developed a series of tools that simulate stellar populations, occultation light curves (including noise), onboard detection and our fitting routines. We describe all the routines and the simulation pipeline as well as details of the detection algorithms, including statistical arguments. Results of expected rates for different model populations are also presented, demonstrating the anticipated performance and event yield for the mission. These simulations show how Whipple will measure size distributions as a function of (three dimensional) position for these populations.

436 *The Sun II* Poster Session *Exhibit Hall*

436.01 **Magnetic Advection due to Diffusivity Gradients E. J. Zita¹** ¹Evergreen State College.

Exhibit Hall We have derived the advection of magnetic fields in plasmas, due to gradients in diffusivity, for a completely general case. Magnetic diffusivity is proportional to electrical resistivity. Where the *value* of this parameter is high, it is well known that magnetic fields can leak (or diffuse) rapidly into (or out) of the plasma. Where *gradients* are high, i.e. the diffusivity changes rapidly in space, magnetic fields can experience enhanced advection. We derive this phenomenon rigorously, and discuss its implications, e.g. for the solar dynamo. We also find that this magnetic advection can be expressed in terms of a diffusion equation within the induction equation, making its computational implementation especially simple.

We present results of simulations of the effect generated with a magnetohydrodynamic model.

We are grateful to Tom Bogdan for discussions about the mathematical derivation, and to Neal Hurlburt for the use of his MHD code. This work was supported in part by Evergreen's Sponsored Research Program, and by NSF grant 0807651. We are grateful to HAO/NCAR in Boulder, CO and Lockheed Martin Solar and Astrophysics Lab in Palo Alto, CA for their support during the performance of this work.

436.02

The Search for Molecular Hydrogen in the IR Second Solar Spectrum

Amanda White¹, J. R. Kuhn²

¹Drexel University, ²Institute for Astronomy, University of Hawai'i. Exhibit Hall

Molecular hydrogen in sunspots should be a dominant molecular species and an important factor in spot dynamics. The rotational and vibrational transitions of molecular hydrogen are extremely weak in comparison to the overall intensity spectrum of the sun making the molecule difficult to observe. Molecular lines, however, are prominent in the linearly polarized spectrum of the sun, also called the Second Solar Spectrum. Using the Scatter-free Observatory for Limb Active Regions and Coronae (SOLAR-C) located on the summit of Haleakala and a spectropolarimeter, we have observed the linear polarized spectrum of the sun near the 2.128 micron line of molecular hydrogen and begun to catalog the second solar spectrum in the IR.

This work was conducted as part of a Research Experience for Undergraduates (REU) position at the University of Hawai'i's Institute for Astronomy and funded by the NSF.

436.03

Re-examination of Stellar Interior Opacities and the Solar Abundances Problem

Anil Kumar Pradhan¹, S. N. Nahar¹, M. Pinsonneault¹, J. E. Bailey²

¹Ohio State Univ., ²Los Alamos National Laboratory.

Exhibit Hall

New solar abundances (Asplund etal., ARAA, 47, 522, 2009) are widely discordant with the 'standard' abundances. It has been suggested that a marginal, but significant, enahancement in stellar interior opacities might resolve the issue, which otherwise results in discrepancies of up to 50% in light elements such as C, N, O and Ne. We report on theoretical and experimental investigations of stellar interior opacities in general, and the the solar radiative/convection zone boundary in particular. We especially examine the atomic physics employed in existing opacities calculations, such as the Opacity Project and OPAL, and find that fundamental processes may not have been accounted for accurately; to wit: the assumption that autoionizing resonances can be treated as lines. It is well known that inner-shell electronic transitions in complex atomic species, such as Iron, account for most of the opacity. But they generally lie in the bound-free continuum and should be resolved as freqency dependent resonance profiles in photoionization cross sections, rather than considered as bound-bound transitions in opacities calculations. Recent work shows that there may be sufficient and significant uncertainty in current opacities, at least at the level of 10% in Rosseland Mean Opacities, to address if not resolve the solar abundances problem, given the inverse correlation between opacities and abundances. Simultaneously with our theoretical investigation, there is a major experimental effort to measure monochromatic opaciites for the first time in stellar interior conditions. The inertial confinement fusion Z-pinch facility at the Sandia National Laboratory is now capable of producing plasmas at conditions prevalent at the boundary of the convection zone (BCZ) in the Sun. Preliminary measurements of monochromatic opacity of iron ions, the primary determinant of effective opacity, differ from theoretical models. We present first results from a new high-precision opacities code HIPOP using new atomic parameters.

Thursday, January 13, 2011, 10:00 AM - 11:30 AM 401 *Exoplanet Detection: Radial Velocities* Oral Session

Ballroom 6A

401.01

Precision Radial Velocities in the near-infrared Y and H bands with the Penn State Pathfinder Instrument

Suvrath Mahadevan¹, L. Ramsey¹, S. Redman¹, C. Bender¹, B. Botzer¹, R. Terrien¹, S. Osterman², S. Diddams³, G. Ycas³, F. Quinlan³, A. Roy⁴, S. Zonak⁵

¹Penn State, ²CASA, University of Colorado, ³National Institute of Standards and Technology,, ⁴Caltech, ⁵Goddard Space Flight Center.

10:00 AM - 10:10 AM

Ballroom 6A

Precision radial velocities in the near infrared can help detect terrestrial mass planets around mid and late M dwarfs that are typically too faint in the optical for effective monitoring. We have demonstrated ~10-15 m/s radial velocity precision in the NIR Y band with our warm-bench fiber-fed Pathfinder instrument at the 9m Hobby Eberly telescope, and will present these results as well as discuss results from the first on-sky observations with an H band laser frequency comb. We will also present the instrumental upgrades and modification to Pathfinder that have made high NIR velocity precision possible with the use of new calibration sources like Uranium lamps and laser combs. The ability to achieve this level of precision with a test bed bodes well for a stabilized spectrograph built on these principles, and we discuss progress toward this as well as challenges like modal noise and telluric absorption correction.

401.02

First Stellar Radial Velocities with a Laser Frequency Comb: Observations in the NIR H Band

Steve Osterman¹, S. Diddams², F. Quinlan², G. Ycas³, S. Mahdevan⁴, L. Ramsey⁴, C. Bender⁴, S. Redman⁴, R. Terrien⁴, B. Botzer⁴

¹Center for Astrophysics and Space Astronomy, University of Colorado, ²Time and Frequency Division, National Institute of Standards and Technology, ³Department of Physics, University of Colorado, ⁴Department of Astronomy & Astrophysics, Pennsylvania State University.

10:10 AM - 10:20 AM

Ballroom 6A

Advances in high precision radial velocity spectroscopy have been hindered by the lack of suitable wavelength references. This has been especially the case in the infrared where until recently radial velocity precision has been limited to ~ 50-100m/s, hindering investigations such as the search for extrasolar planets orbiting cooler M stars at these wavelengths. To redress deficiency this we have developed a 25GHz laser frequency comb spanning the H band and suitable for use with spectrographs with spectral resolution in the range of 40,000 - 60,000, with RV precision limited by instrument stability and object S/N rather than by the lack of a suitable wavelength standard.

We will present CU/NIST frequency comb performance and results obtained using the Pennsylvania State University's Pathfinder Spectrograph on the Hobby Eberly Telescope and will discuss lessons learned.

401.03D

Precise Near-Infrared Radial Velocities with the TripleSpec Exoplanet Discovery Instrument (TEDI) Philip Muirhead¹, J. Edelstein², D. J. Erskine³, K. M. Hamren¹, K. R. Covey¹, J. P. Lloyd¹

¹Cornell University, ²University of California, ³Lawrence Livermore National Laboratory.

10:20 AM - 10:40 AM

Ballroom 6A

Attaining 10 m/s of Doppler velocity precision with near-infrared (NIR) spectroscopy enables the detection and mass measurement of terrestrial-mass and larger exoplanets orbiting mid-to-late M dwarf stars. This is especially exciting considering that JWST has the sensitivity to detect oxygen, an indicator of life, in the atmospheres of terrestrial planets transiting mid-to-late M dwarfs. Radial velocities are required to verify planetary transits. TEDI is an instrument on the Palomar Hale Telescope designed to measure precise NIR radial velocities. It is the combination of a variable-delay interferometer and TripleSpec, a resolution 2700 spectrograph covering 1.0 to 2.5 microns simultaneously. This technique has the potential for broad implementation on 4-meter-class telescopes, for both NIR RV measurements and high-resolution NIR spectroscopy. I will describe the instrument, method, data analysis, and recent results from TEDI, as all are a part of my Ph.D. dissertation at Cornell.

401.04D

Precision Radial Velocity Measurements in the Near-Infrared

Stephen L. Redman¹ ¹*Pennsylvania State University.* 10:40 AM - 11:00 AM

Ballroom 6A

We have investigated and quantified several aspects of making precision radial velocity measurements in the near infrared (NIR) using the PSU Pathfinder --- a high-resolution, fiber-fed echelle spectrograph designed to reach the &It; 10 m/s precision level. At this precision, we could potentially find multi-Earthmass planets in the Habitable Zone (HZ) around late M dwarfs. The issues we have investigated include issues with our IR array, modal noise, and suitable calibration sources. Along with the rest of the PSU Pathfinder team, We have performed several observations with our instrument, including measurements of the Earth's rotational velocity with respect to the Solar spectrum (where we were able to achieve precisions of 7 - 14 m/s), and on-sky observations of bright planet-hosting and RV standard stars at the Hobby-Eberly Telescope. We will report on the results of these observations, as well as the merits of our primary NIR calibration source, Uranium Neon.

402 *Exoplanet Atmospheres - Modeling and Observations* Oral Session *Ballroom 6B*

402.01 Equilibrium Chemistry of the Atmospheres of Scorched Rocky Exoplanets Laura Schaefer¹, K. Lodders¹, B. Fegley, Jr.¹ ¹Washington Univ.. 10:00 AM - 10:10 AM Ballroom 6B The Kepler and COROT missions and Earth-based observations detected putative rocky exoplanets. Some of the planets are exposed to extreme temperatures as they orbit close to their host stars, e.g., CoRot-7b. Such planets can develop atmospheres through (partial) vaporization of their exterior crusts from 500 - 4000 K and total pressures from 10^{-6} to $10^{+2.5}$ bars. The major gas phase species formed by the volatile elements H, C, N, O, and S, and the lithophile elements Na, K, Fe, Si, Mg, Al, Ca, and Ti are H_2O and CO_2 at low temperatures, and Na, K, O_2 , SiO, and O at high temperatures. The effects on overall elemental composition of the evaporated systems will be discussed. The computational results will be useful in planning spectroscopic studies of the atmospheres of hot Earth-like exoplanets. This work was supported by the NSF Astronomy Program and the NASA Astrobiology Program.

402.02

Carbon-rich Planets

Nikku Madhusudhan¹, J. Harrington², K. B. Stevenson², S. Nymeyer², C. J. Campo², P. J. Wheatley³, D. Deming⁴, J. Blecic², R. A. Hardy², N. B. Lust², D. R. Anderson⁵, A. Collier-Cameron⁶, L. Hebb⁷, C. Hellier⁵, P. F. L. Maxted⁵, UCF Exoplanet Team, superWASP Team

¹Princeton University, ²University of Central Florida, ³University of Warwick, United Kingdom, ⁴NASA Goddard Space Flight Center, ⁵Keele University, United Kingdom, ⁶University of St. Andrews, United Kingdom, ⁷Vanderbilt University.

10:10 AM - 10:20 AM

Ballroom 6B

We have recently discovered the first carbon-rich planetary atmosphere. In this talk, we will present the atmospheric composition and temperature structure of this exoplanet, along with the modeling technique that revealed the exotic atmosphere. We used a Bayesian analysis to constrain the atmospheric properties of this exoplanet based on broadband photometric observations. Carbon-rich planets present a new regime in atmospheric chemistry and temperature structure, planetary interiors, planet formation, and astrobiology. We will discuss these various aspects and their observable signatures.

402.03

Light Scattering from Exoplanet Oceans and Atmospheres

Michael Zugger¹, J. F. Kasting², D. M. Williams³, T. J. Kane¹, C. R. Philbrick⁴

¹Penn State University, Applied Research Laboratory, ²Penn State University, Department of Geosciences, ³Penn State Erie: The Behrend College, School of Science, ⁴North Carolina State University, Department of Physics.

10:20 AM - 10:30 AM

Ballroom 6B

Orbital variation in reflected starlight from exoplanets could eventually be used to detect surface oceans. Exoplanets with rough surfaces, or dominated by atmospheric Rayleigh scattering, should reach peak brightness in full phase, orbital longitude = 180deg, whereas ocean planets with transparent atmospheres should reach peak brightness in crescent phase near OL = 30deg. Application of Fresnel theory to a planet with no atmosphere covered by a calm ocean predicts a peak polarization fraction of 1 at OL = 74deg; however, our model shows that clouds, wind-driven waves, aerosols, absorption, and Rayleigh scattering in the atmosphere and within the water column, dilute the polarization fraction and shift the peak to other OLs. Observing at longer wavelengths reduces the obfuscation of the water polarization signature by Rayleigh scattering but does not mitigate the other effects. Planets with thick Rayleigh scattering dilute and shift this peak to smaller OL. A shifted Rayleigh peak might be mistaken for a water signature unless data from multiple wavelength bands are available. Our calculations suggest that polarization alone may not positively identify the presence of an ocean under an Earth-like atmosphere; however polarization adds another dimension which can be used, in combination with unpolarized orbital light curves and contrast ratios, to detect extrasolar oceans, atmospheric water

aerosols, and water clouds. Additionally, the presence and direction of the polarization vector could be used to determine planet association with the star, and constrain orbit inclination.

This research was funded by the NASA Astrobiology Institute, the University of Washington Virtual Planetary Laboratory, and the Penn State Astrobiology Institute. Authors M. Zugger, J. Kasting, and D. Williams are members of the Penn State Center for Exoplanets and Habitable Worlds.

402.04

Transmission Spectra of Transiting Planet Atmospheres: Simulations of the Hot Neptune GJ 436b and Prospects for JWST

Megan Shabram¹, J. J. Fortney¹, T. P. Greene², R. S. Freedman³

¹University of California, Santa Cruz, ²NASA Ames Research Center, ³SETI Institute.

10:30 AM - 10:40 AM

Ballroom 6B

We explore the transmission spectrum of the Neptune-class exoplanet GJ 436b, including the possibility that its atmospheric opacity is dominated by a variety of non-equilibrium chemical products. We also validate our transmission spectrum code by performing tests for model atmospheres that use purely analytic Rayleigh scattering and water vapor opacities. For GJ 436b, the relative coolness of the planet's atmosphere, along with its implied high metallicity, may make it dissimilar in character compared to "hot Jupiters." Some recent observational and modeling efforts suggest low relative abundances of H2O and CH4 present in GJ 436b's atmosphere, compared to calculations from equilibrium chemistry. We include these characteristics in our models and examine the effects of absorption from methane-derived higher order hydrocarbons. To our knowledge, the effects of these non-equilibrium chemical products on the spectra of close-in giant planets have not previously been investigated. Significant absorption from HCN and C2H2 are found throughout the infrared, while C2H4 and C2H6 are less easily seen. We perform detailed simulations of JWST observations, including all likely noise sources, and find that we will be able to constrain chemical abundance regimes from this planet's transmission spectrum. For instance, the width of the features at 1.5, 3.3, and 7 microns indicates the amount of HCN versus C2H2 present. The NIRSpec prism mode will be useful due to its large spectral range and the relatively large number of photo-electrons recorded per spectral resolution element. However, extremely bright host stars like GJ 436 may be better observed with higher spectroscopic resolution mode in order to avoid detector saturation. We find that observations with the MIRI low resolution spectrograph should also have high signal-to-noise in the 5 - 10 microns range due to the brightness of the star and the relatively low spectral resolution ($R \sim 100$) of this mode.

402.05

Advances in the Theory of Giant Exoplanets

David S. Spiegel¹, A. Burrows¹ ¹Princeton University. 10:40 AM - 10:50 AM Ballroom 6B

We review recent results on the spectra of giant planets, including calculations specific to objects in the Kepler field (HAT-P-7b and TrES-2), and calculations of emergent radiation and transit spectra associated with general circulation models. We also present recent results on the potential habitability of terrestrial planets on eccentric orbits.

Constraining Tidal Dissipation in Stars and Destruction Rates of Exoplanets Brian Jackson¹, K. Penev², R. Barnes³

¹Goddard Space Flight Center, ²Harvard CfA, ³University of Washington.

10:50 AM - 11:00 AM

Ballroom 6B

Several recent studies have shown that the orbits of most transiting extra-solar planets, with periods of order a few days, are not stable against tidal decay. If the host star rotates slowly enough, tidal dissipation within the star causes the planet to spiral in over many millions or billions of years. Because the rate of tidal decay increases rapidly as orbital semi-major axis drops, planets that start out very close to their host stars are quickly destroyed, while planets farther out require more time. We calculate the times left for known transiting exoplanets as a function of the rate of tidal dissipation within the host star. For a population of such planets, we expect to observe a minority of planets near the end of their lives since those planets will only survive for a short time more. For an assumed tidal dissipation rate, if we find instead that a majority of transiting planets have only a small fraction of the lifetimes left before destruction, we can conclude the assumed tidal dissipation rate is too large. Thus, we can estimate the rate of tidal dissipation within planet-hosting stars by considering the distributions of times left of transiting planets for a range of assumed dissipation rates. We must also account for important selection and observational biases. Our results based on such an analysis suggest stellar dissipation rates corresponding to tidal Q-values of 10⁶ and larger are consistent with observations, while values of 10⁵ and smaller are not. Given these constraints, we estimate the rates of tidal destruction of transiting exoplanets.

402.07

Balancing the Budget: Albedo and Heat Recirculation on Hot Jupiters Nicolas B. ${\rm Cowan}^1$

¹Northwestern University. 11:00 AM - 11:10 AM

Ballroom 6B

The day-side and night-side effective temperatures of a hot Jupiter constrain its Bond albedo and heat recirculation efficiency. We describe a simple but robust way to convert a series of observed brightness temperatures at different wavebands into a single effective temperature. We then define a sample of 24 transiting short period planets that have at least one published infrared eclipse depth, and in some cases infrared phase amplitudes and/or optical constraints. We determine the probability distribution function for this sample in the albedo-recirculation plane, and find it consistent with uniformly low Bond albedos, but with a variety of recirculation efficiencies. We show that the hottest of these planets exhibit uniformly low recirculation efficiencies, and offer a possible explanation for this trend. NBC is supported by a CIERA Fellowship.

402.08

HST/WFC3 Observations of Giant Hot Exoplanets

Drake Deming¹, E. Agol², A. Burrows³, D. Charbonneau⁴, M. Clampin¹, J. Desert⁴, R. Gilliland⁵, H. Knutson⁶, N. Madhusudhan³, A. Mandell¹, S. Seager⁷, A. Showman⁸ ¹NASA's GSFC, ²Univ. of Washington, ³Princeton Univ., ⁴CfA, ⁵STScI, ⁶Univ. of California, ⁷MIT, ⁸Univ. of Arizona. 11:10 AM - 11:20 AM

Ballroom 6B

Low resolution thermal emission spectra of over two dozen extrasolar planets have been measured using Spitzer, and HST observations of a few key exoplanets have defined molecular abundances via transmission spectroscopy. However, current models for the atmospheric structure of these worlds exhibit degeneracies wherein different combinations of temperature and molecular abundance profiles can fit the same Spitzer data. The advent of the IR capability on HST/WFC3 allows us to address this problem. We are currently obtaining transmission spectroscopy of the 1.4-micron water band in a sample of 13 planets, using the G141 grism on WFC3. Among the abundant molecules, only water absorbs at this wavelength, and our measurement of water abundance will enable us to break the degeneracies in the Spitzer results with minimal model assumptions. We will also use the G141 grism to observe secondary eclipses for 7 very hot giant exoplanets at 1.5-microns, including several bright systems in the Kepler and CoRoT fields. The strong temperature sensitivity of the thermal continuum at 1.5-microns provides high leverage on atmospheric temperature for these worlds, again helping to break degeneracies in interpreting the Spitzer data. We here describe preliminary results for several exoplanets observed in this program.

403

Dark Matter & Dark Energy Oral Session Ballroom 6C

403.01

Orientations of Galaxies within their Dark Matter Halos Tereasa G. Brainerd¹, I. Agustsson¹

¹Boston Univ.. 10:00 AM - 10:10 AM Ballroom 6C

The most popular theory of galaxy formation, cold dark matter, predicts that large, bright galaxies form at the centers of massive, triaxial dark matter halos. Observational evidence for the existence of large dark matter halos is overwhelming; however, there are precious few constraints on the shapes of the dark matter halos and on the ways in which the galaxies are be embedded within the halos. Here we present an analysis of the locations of the satellites of relatively isolated host galaxies in the Sloan Digital Sky Survey (SDSS) and the Millennium Run simulation. The SDSS satellites are distributed aniostropically about their host galaxies, and the degree of anisotropy is a strong function of the colors and stellar masses of the hosts. Provided we use two distinct prescriptions to embed luminous galaxies within the simulated dark matter halos (ellipticals share the triaxial shapes of their halos), we obtain a good agreement between observation and theory. If we instead require near-perfect alignment of mass and light for host galaxies of all morphological types, we cannot reproduce any of the observed trends of satellite galaxy locations in the SDSS. We conclude that mass and light are reasonably aligned in large elliptical galaxies, but that mass and light are, in general, not well-aligned in large disk galaxies. We are grateful for support from the NSF under contract AST-0708468.

403.02D

Multi-Epoch Galaxy Modeling for Shear and Morphology Measurement James Bosch^1

¹University of California, Davis. 10:10 AM - 10:30 AM

Ballroom 6C

Future weak lensing surveys will require control of errors in shear measurement to a degree that is currently impossible even with simplified simulated image data. The observing strategies of many current and future surveys -- which result in many exposures of each patch of sky, each with a different point spread function (PSF) -- complicate the shear estimation problem further, as it has become clear that current image co-addition methods will not suffice. Multi-epoch simultaneous fitting ("multifit") is a promising alternative, but it requires flexible, general models to avoid problems (including multiplicative shear biases) with underfitting. By constructing "eigenmorphology" basis functions using Gauss-Hermite functions and a training set of well-resolved galaxies, we develop a class of galaxy models that can represent complex morphologies with a relatively small number of linear parameters, providing the needed flexibility and modeling power for multifit while retaining the computational efficiency necessary for an algorithm that must be applied to surveys of billions of galaxies observed hundreds of times.

403.03D

The Dark Matter Halo Profile Of NGC 2976 Via Stellar Kinematics

Joshua J. Adams¹, K. Gebhardt¹, G. J. Hill¹, R. C. E. van den Bosch², G. A. Blanc¹ ¹Univ. of Texas at Austin, ²Max Planck Institute for Astronomy, Germany. 10:30 AM - 10:50 AM

Ballroom 6C

The observations of kinematics in low surface brightness (LSB) and dwarf late type galaxies have stubbornly resisted giving clear evidence for the cuspy Navarro-Frenk-White (NFW) dark matter (DM) halo profiles that simulations with Λ CDM inputs predict. Instead, most LSBs and late type dwarfs suggest cored DM halos or

the observations are not yet constraining enough to rule out cusps. One viable theory to explain cored DM halos relies on the gravitational perturbation of a growing baryonic disk that is then rapidly removed causing the halo to expand to a cored equilibrium. Weakly self-interacting dark matter has also been invoked to explain cored DM halos. This problem may loom large over small galaxy formation and growth. However, different measurements can be taken to further test the apparent problem. Most previous data have relied on HI or H α as kinematic tracers. A small number of works have studied the problem with longslit stellar kinematics. Ideally, the advantages of 2D spectroscopic coverage and a collisionless kinematic tracer would be combined. So far, NGC 2976 has made one of the cleanest cases for a cored DM halo via integral field spectroscopy in H α . We here report on observations of NGC 2976 with the large field-of-view fiber-fed Visible Integral field Replicable Unit Spectrograph Prototype (VIRUS-P) at R=3200 to concurrently measure the gaseous and stellar kinematics and probe the DM halo. We find that the gas and stellar kinematics disagree both in the magnitude of their second velocity moments and their detailed profiles. We unexpectedly find emission features in one of NGC 2976's two large star-forming regions which may be indicative of carbon-rich Wolf-Rayet stars. A putative bar further complicates the use of gaseous tracers. We solve the Jeans equations with stellar kinematics to reevaluate the DM profile in this exemplar galaxy of the core-cusp problem.

403.04

Looking Beyond the Optical to Help Supernova Cosmology Bradley E. Tucker¹, B. Schmidt¹, ESSENCE Project ¹Australian National University, Research School of Astronomy and Astrophysics, Australia. 10:50 AM - 11:00 AM

Ballroom 6C

The use of type Ia supernova (SN Ia) as standard candles has shifted from testing whether the Universe is accelerating to making a precision measurement of the dark energy equation of state to test the current Lambda-CDM paradigm. However, we still lack a clear understanding of the SN Ia progenitor systems, and recently discovered subtle evolution in their properties depending on environment has the potential to halt progress in improving cosmological measurements. By investigating the host galaxies of type Ia supernova, we can gain important insights into the supernova while improving our determination of the dark energy equation of state. In order to maximize our knowledge of the SN environments, we must look outside the optical wavelengths, namely to the ultraviolet and infrared. I will show the effects of host galaxy using Far-UV to Near-IR observations of both nearby and high redshift supernova, and describe how our understanding of these systems has changed form purely optical wavelength observations. These results will improve with future planned observations.

403.05

Dark Matter Determinations from Chandra Observations of Quadruply Lensed Quasars

David A. Pooley¹ ¹Eureka Scientific. 11:00 AM - 11:10 AM Ballroom 6C

I present *Chandra* observations of 14 quadruply lensed quasars. The X-ray data reveal flux ratio anomalies which are more extreme than those seen at optical wavelengths, confirming the microlensing origin of the anomalies originally seen in the optical data. The X-ray emitting regions are essentially point sources and therefore give a microlensing signal unencumbered by source size considerations. For each lensing galaxy, I present the most likely ratio of smooth material (dark matter) to clumpy material (stars) to explain the X-ray flux ratios. The ensemble of *Chandra*-observed quads indicates that the amount of matter projected along the lines of sight to the images is about 90% smooth dark matter and 10% stars.

403.06

Astrometric Microlensing by Local Dark Matter Subhalos

Adrienne L. Erickcek¹, N. M. Law²

¹CITA/Perimeter Institute, Canada, ²Dunlap Institute for Astronomy and Astrophysics, University of Toronto, Canada.

11:10 AM - 11:20 AM

Ballroom 6C

High-resolution n-body simulations of galaxy-sized dark matter halos predict that the Milky Way contains numerous subhalos. Moreover, subhalos with masses greater than 10^6 solar masses are present within ten kiloparsecs of the center of the simulated halo, indicating that there are dark matter subhalos between the Sun and other stars within the Galaxy. When a subhalo passes in front of a star, the light from that star will be deflected by gravitational lensing, leading to a small change in the star's apparent position. This astrometric microlensing signal depends on the inner density profile of the subhalo and can be greater than a few microarcseconds for an intermediate-mass subhalo (post-stripping mass > 100 solar masses) passing within arcseconds of a star. Recent developments in high-precision astrometry make it possible to detect this unique signature of local dark matter substructure.

We develop a general formalism to calculate a subhalo's astrometric lensing cross section over a wide range of masses and density profiles, and we calculate the lensing event rate by extrapolating the subhalo mass function predicted by simulations down to the subhalo masses potentially detectable with this technique. We find that, although the detectable event rates are predicted to be low on the basis of current simulations, a large-area survey with an astrometric precision of 10 microarcseconds should observe lensing events if most of the dark matter is contained in small subhalos that have more than 1 solar mass within 0.1 pc of the subhalo centers. Furthermore, targeted astrometric observations can be used to confirm the presence of a nearby subhalo detected by gamma-ray emission. We show that, for sufficiently steep density profiles, ground-based adaptive optics astrometric techniques should be capable of detecting intermediate-mass subhalos within 100 parsecs.

403.07

Revealing the Invisible: Strong Lensing Views and Clues of the Nature of Dark Matter Particle(s) Leonidas A. Moustakas¹, OMEGA Explorer Science Team

¹JPL/Caltech.

11:20 AM - 11:30 AM

Ballroom 6C

The amount of dark matter and its distribution in the universe has been mapped extremely well. So far, the nature of the fundamental particle or particles that make up dark matter has remained elusive. An emerging frontier with surprisingly discriminating power lies within galaxies: different dark matter particles can lead to vastly different properties in the predicted cohesiveness and statistics of dark matter sub-structure within galaxies. These structures need not host stars or gas, which would render them visible through established searching techniques. Their gravitational presence, however, cannot be hidden. Many galaxies act as strong gravitational lenses, producing multiple images of distant active galactic nuclei. With a tailored experiment, observing time-dependent and multi-wavelength variations in such strong lenses can reveal the statistics of otherwise-invisible sub-structures. These measurements can be connected to predictions of structure formation and evolution from different dark matter particle candidates, and some ruled out or their properties mapped, in a way that is completely independent and complementary to other methods of probing (or producing) dark matter. The OMEGA Explorer is developed to perform this experiment.

404 Black Holes

Oral Session Room 611/612

404.01D

The Physics Of Disk Winds, Jets, And Fast X-ray Variability In The Microquasar GRS 1915+105 Joseph Neilsen¹

¹Harvard University. 10:00 AM - 10:20 AM Room 611/612

I present new insights about accretion and ejection physics based on two high-resolution X-ray studies of strong variability in the microquasar GRS 1915+105. First, we use 10 years of Chandra HETGS observations to probe the long-term connection between the accretion disk wind and the radio jet. We find that the strength of the wind and the jet are anticorrelated, and that the wind carries enough matter away from the black hole to suppress the jet. Thus mass ejection is regulated in GRS 1915+105. Second, we perform the very first fast phase-resolved spectroscopy of a variability class in GRS 1915+105. For the first time, we are able to show that changes in the broadband X-ray spectrum (RXTE) on timescales of seconds are associated with measurable changes in absorption lines (Chandra HETGS) from the accretion disk wind. Our X-ray data thus reveal the black hole as it ejects a portion of the inner accretion flow and then drives a wind from the outer disk in a bizarre cycle that last fewer than 60 seconds but repeats for days. Our results indicate that the accretion disk wind may play an integral role
in GRS 1915+105, not only in quenching the jet on long and possibly short timescales, but also in producing or facilitating transitions between classes of X-ray variability.

404.02

The Spin-Jet Connection for XTE J1550-564

James F. Steiner¹, J. E. McClintock², R. C. Reis³, L. Gou², R. A. Remillard⁴ ¹Harvard University, ²Harvard-Smithsonian Center for Astrophysics, ³University of Cambridge, United Kingdom, ⁴MIT Kavli Institute for Astrophysics and Space Research. 10:20 AM - 10:30 AM

Room 611/612

The microquasar XTE J1550-564 (J1550) produced the very first X-ray jets to be observed from a black hole X-ray binary. By modeling its spectrum of X-ray emission, we have measured J1550's spin parameter using both the continuum-fitting and iron line techniques. At the same time, we have exploited a nearly unique opportunity to track the propagation of black hole jets over long timescales using Chandra imaging data obtained during 2000-2003. We examine the implications of these jet models for black hole spin measurements, and the connection between black hole spin and the production of relativistic jets.

404.03

LMC X-1: Black Hole Wind Accretion++

Laurel Ruhlen¹, D. M. Smith¹

¹UC Santa Cruz.

10:30 AM - 10:40 AM

Room 611/612

The wind accretor LMC X-1, along with LMC X-3 and Cygnus X-1, is one of only three known persistently bright black hole binary systems. Our long-term RXTE monitoring campaign of LMC X-1 has revealed a surprising departure from the typical accretion disk temperature-luminosity relation. This behavior is consistent with the presence of a stable accretion disk whose inner regions suffer variable amounts of veiling by a population of hot electrons. We show that our model agrees well with current theories of O-star winds and well-established thin-disk accretion models, as well as with x-ray observations of two recently discovered extragalactic wind-accreting black hole binary systems.

404.04D

The Co-Evolution of Merging Supermassive Black Hole Binaries and Their Accretion Disks: Emission Models and Prospects for Detection

Takamitsu Tanaka¹

¹Columbia University.

10:40 AM - 11:00 AM

Room 611/612

Supermassive black hole binaries are expected to form and coalesce throughout cosmic time. The prospects of detecting a merger of two supermassive black holes have never been better. Recent breakthroughs in numerical relativity have made possible precise predictions for the gravitational-wave signature of coalescence; and the planned space-based detector *LISA* is expected to measure this signature with extremely high fidelity. If the coalescence event also has a detectable electromagnetic signature, e.g. from the interaction of the rapidly merging binary with the surrounding gas, then identifying this emission together with the gravitational-wave observation will allow cosmological studies by identifying the source redshift. Such a concomitant observation would also present a unique opportunity to study the accretion flows around black holes whose masses and spins are precisely known. I will discuss a simple thin-disk model for the co-evolution of the binary and the circumbinary

gas disk, and describe the time-dependent features of the emission that could help distinguish such merging or recently merged binary systems from AGN and quasars fueled by a solitary black hole.

404.05 Black Hole Universe Model and Dark Energy Tianxi Zhang¹

¹Alabama A&M University. 11:00 AM - 11:10 AM Room 611/612

Considering black hole as spacetime and slightly modifying the big bang theory, the author has recently developed a new cosmological model called black hole universe, which is consistent with Mach principle and Einsteinian general relativity and self consistently explains various observations of the universe without difficulties. According to this model, the universe originated from a hot star-like black hole and gradually grew through a supermassive black hole to the present universe by accreting ambient material and merging with other black holes. The entire space is infinitely and hierarchically layered and evolves iteratively. The innermost three layers are the universe that we lives, the outside space called mother universe, and the inside star-like and supermassive black holes called child universes. The outermost layer has an infinite radius and zero limits for both the mass density and absolute temperature. All layers or universes are governed by the same physics, the Einstein general relativity with the Robertson-Walker metric of spacetime, and tend to expand outward physically. When one universe expands out, a new similar universe grows up from its inside black holes. The origin, structure, evolution, expansion, and cosmic microwave background radiation of black hole universe have been presented in the recent sequence of American Astronomical Society (AAS) meetings and published in peer-review journals. This study will show how this new model explains the acceleration of the universe and why dark energy is not required. We will also compare the black hole universe model with the big bang cosmology.

405

Astronomy Education Research Oral Session Room 615/617

405.01

The Astronomy and Space Science Concept Inventory: Assessment Instruments Aligned with the K-12 National Science Standards

Philip M. Sadler¹

¹Harvard-Smithsonian, CfA. 10:00 AM - 10:10 AM Room 615/617

We report on the development of an item test bank and associated instruments based on those K-12 national standards which involve astronomy and space science. Utilizing hundreds of studies in the science education research literature on student misconceptions, we have constructed 211 unique items that measure the degree to which students abandon such ideas for accepted scientific views. Piloted nationally with 7599 students and their 88 teachers spanning grades 5-12, the items reveal a range of interesting results, particularly student difficulties in mastering the NRC Standards and AAAS Benchmarks. Teachers generally perform well on items covering the standards of the grade level at which they teach, exhibiting few misconceptions of their own. Teachers dramatically overestimate their students' performance, perhaps because they are unaware of their students' misconceptions. Examples are given showing how the developed instruments can be used to assess the effectiveness of instruction and to evaluate the impact of professional development activities for teachers.

405.02

Prior Preparation in Math and Science and its Effect on Student Performance in an Introductory Physics Course

Jeffrey J. Sudol¹

¹West Chester University.

10:10 AM - 10:20 AM

Room 615/617

I developed a test, hereafter the Baseline Test, to measure the extent to which students meet the expectations of a college level, algebra-based, introductory physics course with regard to prior preparation in math and science. The average Baseline Test score for a sample of N=182 undergraduate students is 0.55 ± 0.18, consistent with past efforts to make similar measurements. Positive correlation is found between Baseline Test scores and average exam scores (r=0.57, p < 0.0001, N=144). Positive correlation is also found between Baseline Test scores and Force Concept Inventory gains (r=0.45, p < 0.0001, N=141). An analysis of the complete record of student responses to each of the Baseline Test questions and the multiple choice questions on exams reveals no apparent, causal relationship between prior preparation in math and science and student performance on exams. The data suggest the presence of a hidden variable.

405.03

Unexpected Challenges in Teaching Students How to Use Light Curves

Timothy F. Slater¹, S. J. Slater¹, Center for Astronomy & Physics Education Research(CAPER) Team ¹University of Wyoming.

10:20 AM - 10:30 AM

Room 615/617

Graphs are transcriptive, visual representations of data and phenomena that are widely used in astronomy. Indeed, the creation and interpretation of brightness versus time light curves serve a critical role in variable astronomy studies. Students reasoning difficulties in utilizing graphs is well document in physics, but not yet in astronomy. This paper reports preliminary results in astronomy education research focusing on challenges students have in using graphs in astronomy. Many introductory astronomy survey courses, hereafter ASTRO 101, show numerous light curves, including those for decaying supernova, rotating neutron stars, eclipsing binary stars, Cepheid variable stars, among many others. All too often, ASTRO 101 instructors too quickly assume that students understand how to interpret time graphs. Indeed, light curves appear to be quite elementary to most professional astronomers, yet our efforts in astronomy education research are suggesting that novices have considerable difficulty using graphs. There are three primary domains well poised for student reasoning difficulties when using light curves. The first is that learners tend to view a graphical representation as an "iconic" map of the phenomena. The second is that learners tend to confuse the nature of slope and height of a best fit line. The third is students have challenges understanding the difference between a single point and an interval. As such, purposeful instructional strategies need to be employed if professors hope to successfully circumvent these documented learning challenges.

405.04

Strategies for Using the Views on Scientific Inquiry VOSI Instrument for Astronomy Education Research

Stephanie Slater¹, D. J. Lyons¹, T. F. Slater¹, Center for Astronomy & Physics Education Research(CAPER) Team

¹University of Wyoming. 10:30 AM - 10:40 AM

Room 615/617

As astronomy education research, AER, becomes more sophisticated, so increases the number of assessment instruments available to the community. We are finding significant success with the "Views on Scientific Inquiry," or VOSI, instrument for targeting how students' understanding of science's model for progress. Initially developed by Rene Schwartz, Norman Lederman and colleagues, the VOSI is an open-ended written or interview instrument focusing on eliciting elements of scientific inquiry. The VOSI team examined how a number of cross-disciplinary scientists viewed scientific inquiry to create the VOSI. The underlying hope was to find a way to measure enhancements in how students could learn more about scientific inquiry and understand more about how students are apt to go into STEM fields or, at least, become more science literate citizens who value science. The VOSI measures as many as eight categories of science attributes aligned with the goals of education including: descriptive, conceptualization, problem solving, ethical reasoning, scientific values and attitudes, communication, collaboration, and self-assessment. Surprisingly, these categories seem to receive the only a scant amount of attention in a conventional ASTRO 101 class. We propose that a parallel direction for fruitful research and development in astronomy education research is enhanced VOSI scores rather than only enhanced astronomy content knowledge.

405.05

Preliminary Results on Impacts of Backwards Faded Scaffolding Approach on ASTRO 101 Students' Understanding of Scientific Inquiry

Daniel Jonathan Lyons¹, S. J. Slater¹, T. F. Slater¹, Center for Astronomy & Physics Education Research(CAPER) Team

¹University of Wyoming.

10:40 AM - 10:50 AM

Room 615/617

National calls for reformed teaching in introductory science survey courses argue that students should be engaged in scientific inquiry rather than passively learning about scientific facts or memorizing scientific models. Indeed, the National Research Council's 2007 book on Taking Science to School proposes that students who are proficient in science have been repeatedly engaged in at least four domains. Students who are proficient in science: (1) know, use, and interpret scientific explanations of the natural world; (2) generate and evaluate scientific evidence and explanations; (3) understand the nature and development of scientific knowledge; and (4) participate productively in scientific practices and discourse. In response, faculty and students in the Center for Astronomy & Physics Education *Research CAPER Team* have created an approach to engaging students in astronomical research closely aligned with these principles. Called Backwards Faded Scaffolding, the approach turns the traditional sequence of scientific inquiry on its head. The process is to teach students how to construct a scientific conclusion based on evidence before teaching students how to devise an appropriate scientific question and is described elsewhere. As part of a larger effort to systematically isolate and measure the impact of a Backwards Faded Scaffolding approach, we used the Views On Scientific Inquiry, VOSI, instrument to help determine if students in introductory astronomy survey courses, also known as ASTRO 101, were exhibiting enhanced VOSI scores. Our preliminary results show that the participating students are making significant progress in most characteristics observed by the VOSI, but not all. This suggests that the Backwards Faded Scaffolding approach is effective along many of the domains of learning most desired by ASTRO 101 professors.

405.06 **Guided Versus Unguided Learning: Which One To Choose? Angela Speck**¹, L. Ruzhitskaya¹ ¹Univ. of Missouri. 10:50 AM - 11:00 AM *Room 615/617* Abstract 1 **Guided versus unguided learning: which one to choose?**

We present the results of a study that measures the effectiveness of two types of computer-based tutorials for teaching the concept of stellar parallax to non-science major students in a college-level introductory astronomy course. A number of previous studies on the use of computer technology in education suggested that a method of inquiry-based learning rooted in a discovery method must prevail over direct instruction. At the same time, a number of researchers raised a concern that the discovery approach especially in combination with interactive computer-based environments may present students with additional distractions and thus hinder the educational value of such interactions. This study was set to test the both approaches and to identify the preferable method for engaging students in active and meaningful learning.

The study consisted of guided and unguided computer-based tutorials and used a control group in which students were engaged in paper-based exercises. The guided tutorial was an adaptive tutorial that was designed to respond to students' input and to provide them with the next step: an exercise, an animated visualization, or a set of additional questions. The unguided tutorial allowed students to explore any part of the tutorial in any order. Both tutorials consisted of four parts and reviewed simple geometry, trigonometric parallax, angular sizes in astronomy, resolution and conversion of units, and had a concluding chapter on finding distance to a star. The control group used Lecture-Tutorials (Prather, et al) to learn angular sizes and stellar parallax.

The efficacy of each treatment was validated through a 14-question pretest and two posttests to evaluate and contrast students' immediate recall and their long-term knowledge and corroborated by a number of interviews with selected students. We present our preliminary results based on analyzed work of over 200 participants.

405.07

Peer interaction: help or distraction?

Lanika Ruzhitskaya¹, A. Speck, Dr.¹ ¹University of Missouri. 11:00 AM - 11:10 AM

Room 615/617

We present our results on the difference in learning effectiveness of a particular concept in astronomy when students work as individuals as compared to working in pairs. We conducted a study based on the stellar parallax concept using two versions of a computer-based tutorial: guided and unguided. In this study students were randomly assigned to work in peer groups and individually. Students' interactions with the two versions of the tutorial and their peer interactions were recorded using MORAE software for quantitative and qualitative analysis. In addition, we used pretest and two posttest questionnaires to find conceptual gain.

Here we present our preliminary results on the emergence of particular patterns in students learning behavior when they work independently and with peers, and how guided or unguided exercises affect these patterns.

406 *Circumstellar Disks II* Oral Session *Room 618/620*

406.01

Metallicities of 10-100 Myr Open Clusters with Debris Disks

TalaWanda Monroe¹, C. A. Pilachowski¹, A. Roberge², L. Rebull³ ¹*Indiana Univ.,* ²*NASA-GSFC,* ³*Spitzer Science Center, Caltech.* 10:00 AM - 10:10 AM *Room 618/620*

We present chemical abundances obtained from moderate-resolution WIYN-Hydra and CTIO-Hydra spectra of F and G stars in six 10-100 Myr old open clusters observed at 24 microns with Spitzer Space Telescope, including M47, IC 2391, NGC 2232, and NGC 7160. Cluster metallicities are in the range [Fe/H] ~ 0.0-0.3, and our results include abundances of alpha- and light-elements and additional Fe-peak elements. We also present archival Spitzer-MIPS 24 micron photometry for these clusters, to examine the fraction of B and A stars with excess MIR emission as a function of stellar metallicity. The aim of this program is to consider the role that stellar metallicity may play in debris disk frequency and longevity for B and A cluster stars.

Support for this work was provided by the NASA GSFC Graduate Student Researchers Program.

406.02D

The Variable Nature of T Tauri Stars

Jarron Leisenring¹, M. F. Skrutskie¹

¹University of Virginia. 10:10 AM - 10:30 AM Room 618/620

Results from short- and long-term monitoring indicate that variability at all wavelengths is a hallmark of young stellar objects, suggesting that the circumstellar disks should be perceived as evolving, non-static systems. Using the Spitzer Infrared Spectrograph, multiple epochs were observed for a sample of actively accreting T Tauri stars, providing an opportunity to explore the associated temporal variations and to better understand the disk evolution on timescales ranging from days to years.

All objects in this sample exhibit in some form variability over the observed wavelength range, including spectral features such as the 10-micron silicate complex, atomic lines, and a PAH emission. These variations can arise from an array of physical mechanisms, such as changes in accretion or alterations to the disk's overall physical structure and opacity. In order to quantify the observed variations, spectral decomposition models were used to study changes in the dust mineralogy and disk components. For the majority of the sample, the continuum changes in a significant manner, possibly due to asymmetries in the rotating disk structure. Furthermore, in a small percentage of objects, significant changes in the optically thin silicate emission are observed.

In an effort to continue characterizing the circumstellar environments, I have taken a key role in developing LMIRcam, a 3-5 micron imager/spectrograph, for the Large Binocular Telescope. Commissioning of LMIRcam in early 2011 will take advantage of the recent delivery of the LBT's first adaptive secondary, enabling unprecedented resolution for a single-aperture telescope. Fizeau interferometric implementation will be realized after the delivery of the final adaptive secondary. With a resolution of approximately 30 milli-arcseconds, observations with LMIRcam will vastly improve our knowledge and understanding of inner regions of circumstellar disks and planet formation. Furthermore, grism spectroscopy (R~400) will allow for characterization of spectral features in extrasolar planets and spatially resolved circumstellar disks.

406.03

Probing The Circumstellar Environments Of Be Stars With The Chara Array

Yamina Touhami¹, D. R. Gies¹, G. H. Schaefer², N. D. Richardson¹, E. D. Grundstrom³, G. M. V. Mcswain⁴ ¹Georgia State University, ²The CHARA Array, ³Vanderbilt University, ⁴Lehigh University. 10:30 AM - 10:40 AM

Room 618/620

We present the first spatially resolved observations of circumstellar envelopes of 25 bright northern Be stars. The survey was performed with the CHARA Array interferometer in the K-band at intermediate and long baselines. The interferometric visibilities are well fitted by a viscous disk model where the gas density steeply decreases with the radius. Physical and geometrical parameters such as the density profile, the inclination, and the position angles of the circumstellar disks are determined. We find that the density radial exponent ranges between n \approx 2.4-3.2, which is consistent with previous IRAS measurements. By combining the projected rotational velocity of the Be star with the disk inclination derived from interferometry, we give estimates of the equatorial rotational velocities of these Be stars.

406.04

Resolving the Circumstellar Disks of V892 Tau and PV Cep: An Unusual Case Murad Hamidouche $^{\rm 1}$

¹SOFIA/USRA - NASA Ames Research Center.

10:40 AM - 10:50 AM

Room 618/620

The influence of the intermediate-mass Herbig stars on their circumstellar disks is still not well studied and understood. I present new sub-arcsecond radio interferometric CARMA and VLA observations of two disks around two interesting Herbig Ae stars that are in completely different evolutionary stages: V892 Tau & PV Cep. I resolved for the first time their disks as well as the PV Cep outflow. The very young (< 1 Myr) PV Cep disk is the youngest resolved disk around any Herbig Ae star.

By probing these two disks properties, I found that these are consistent with their corresponding stellar ages. But, unlike in the youngest T Tauri and Class 0 stars, the PV Cep disk contains ISM-like unprocessed dust. PV Cep case suggests that the evolutionary processes of Herbig Ae and T Tauri disks could be different in their earliest stages. I discuss the influence of PV Cep on its disk evolution and how this differs from the lower-mass T Tauri stars.

406.05D

Spitzer IRS Observations of Edge-on Protoplanetary Disks and Infrared Companions Andrew J. Kruger¹

¹University of California, Davis.

10:50 AM - 11:10 AM

Room 618/620

Lahuis et al. (2006) showed that Spitzer IRS observations of gas phase molecular absorption toward young stars could be used to determine physical conditions within a few AU of the star. The pencil beam nature of this method requires an edge-on disk geometry with a large column between the observer and the emitting source. Molecular gas absorption has also been detected towards GV Tau N, a classical infrared companion (Koresko et al. 1997) that is likely a circumstellar disk seen near edge-on (Correia et al. 2007). We were granted time with Spitzer IRS to obtain high signal-to-noise spectra of 7 YSOs, three classified as disks seen near edge-on and four classical IRCs, to search for molecular absorption. We present findings from this Spitzer IRS project, along with near-infrared spectroscopy of CO fundamental

transitions and mid-infrared imaging. We find that although DG Tau B shows CO₂ gas absorption at a temperature similar to IRS 46 and GV Tau N, it likely originates from a moderately different region of the disk, indicating that the detection of organic molecules, even in edge-on disks, is highly sensitive to the line of sight. We further find DG Tau B likely displays high amounts of dust grain growth and settling, and we provide support for the VV CrA binary disk geometry where the absorption seen towards the IRC is due to the disk around the Primary being in the line of sight (Smith et al. 2009). This work is supported by NSF grant AST-0708074 and NASA support for Spitzer observations through contract RSA No. 1346810, issued by JPL.

406.06

Diagnosing the beta Pictoris Debris Disk Joseph M. Hahn 1

¹Space Science Institute - Austin. 11:10 AM - 11:20 AM

Room 618/620

A model of a circumstellar debris disk is developed and applied to observations of the circumstellar dust orbiting beta Pictoris (Hahn 2010). This model accounts for dust production via collisions among unseen planetesimals, and grain destruction due to dust-dust collisions, with radiation pressure lofting the smaller grains out to r~1000 AU, which accounts for the disk's large spatial extent. Solving the rate equations that govern dust production and losses due to collisions then provides the dust abundance and collisional lifetime versus grain size, and the debris disk's optical depth and surface brightness versus distance from the star. Comparison to observations then yields estimates of the unseen planetesimal disk's radius, and the rate at which the disk sheds mass due to planetesimal grinding. Fitting the model to optical observations of beta Pic (Golimowski et al 2006) yields good agreement when the unseen planetesimal disk there is broad, spanning 75<r<150 AU. If it is assumed that the dust grains are bright like Saturn's icy rings (albedo Q s=0.7), then the cross section of dust in the disk is ~2x10^20 km^2 and its mass ~10 lunar masses. In this case the planetesimal disk's dust production rate is heavy, ~10 earth-masses/Myr, implying that there is or was a substantial amount of planetesimal mass there, at least 100 earth-masses, in order to sustain the observed dust production over the system's age. But if the dust grains are darker than assumed, then the planetesimal disk's mass-loss rate and its total mass are heavier. In fact, the apparent dearth of any major planets in this region, plus the planetesimal disk's heavy mass-loss rate, suggests that the 75<r<150 AU zone at beta Pic might be a region of planetesimal destruction, rather than a site of ongoing planet formation.

407 *Evolution of Galaxies VIII* Oral Session *Room 608*

407.01

Present-Day Descendants of z=3.1 Lyα Emitting Galaxies in the Millennium-II Halo Merger Trees Jean P. Walker¹, E. Gawiser¹, N. Bond¹ ¹*Rutgers University.* 10:00 AM - 10:10 AM *Room 608* Using the Millennium-II Simulation dark matter sub-halo merger histories, we created mock catalogs of Lyman Alpha Emitting (LAE) galaxies at z=3.1 to study the properties of their descendants. Several models were created by selecting the halos to match the observed LAE median dark matter mass and

number density to study the effects of mass selection on descendant properties. We used assembly,

formation and merger ages to study age dependence on the LAE descendants. For the models which best represent LAEs at z=3.1, the z=0 descendants have a median mass of 10^{12} M_{sun}, with a wide scatter in masses. The z=0 central sub-halos distributions have median masses ~ 10^{12} M_{sun}. Typical descendants of z=3.1 LAEs are therefore L* type galaxies. The median descendant mass is robust to various methods of age determination but could vary by a factor of 4 due to current observational uncertainties in the clustering of LAEs used to determine their median z=3.1 mass. We gratefully acknowledge support from NSF, DOE and NASA.

407.02

Emission Line Profiles of Lyman Alpha Emitting Galaxies at z=2.1 and z=3.1

Eric J. Gawiser¹, M. J. Berry¹, L. Guaita², N. Padilla², E. Treister³, MUSYC Collaboration ¹*Rutgers University*, ²*P.U. Catolica, Chile*, ³*IfA-Hawaii*. 10:10 AM - 10:20 AM

Room 608

We obtained R=1400 VLT+FORS spectra covering 3500-5500 Angstroms for 30 Lyman Alpha Emitting (LAE) galaxies at z=2.1 and z=3.1. Our clustering analyses have revealed these LAEs to be progenitors of present-day L* galaxies like the Milky Way (Gawiser et al. 2007, Guaita et al. 2010a). Most of the Lyman alpha emission lines are resolved at this resolution, with a majority showing multiple velocity components that would appear to be a single component at the lower resolution and S/N of typical spectra. These profiles will be used to constrain models of the radiative transfer of resonantly scattered Ly alpha photons inside these galaxies. We also compare the Ly alpha redshifts with those of restultraviolet interstellar absorption lines (Si II 1260, O I 1302, C II 1334, C IV 1550) to reveal the velocity offsets between the main Ly alpha emission component which comes from the away side of outflowing gas in galactic winds and the absorption originating from gas on the near side. The S/N is high enough to detect these interstellar absorption lines for a few objects, and we use spectral stacking to study them in the rest. Our unique survey design allows a direct comparison of the ISM properties of LAEs at z=2.1 and z=3.1, and we will present evidence for evolution in Lyman alpha emission profiles and velocity offsets between the two epochs. We gratefully acknowledge support from NSF, DOE and NASA.

407.03

Sizing Up Lyman-alpha ad Lyman-break Galaxies at z>2

Sangeeta Malhotra¹, J. Rhoads¹, S. Finkelstein², N. Hathi³, K. Nilsson⁴, E. McLinden¹, N. Pirzkal⁵ ¹Arizona State Univ., ²Texas A & M University, ³Carnegie Observatory, ⁴ESO, Germany, ⁵Space Telescope Science Institute.

10:20 AM - 10:30 AM

Room 608

We show that galaxies grow more luminous only if they grow in linear size. This is because the Luminosity per unit area has a distinct upper limit due to the self-limiting nature of star-formation. As a first corollary to this we show that the observed increase in characteristic luminosity of Lyman-Break Galaxies- L*, with time is due to an increase in size which scales as 1/(1+z). In contrast, Lyman-alpha galaxies have a characteristic, constant size between redshift z=2.25 and 6.5, which explains the constant luminosity function as measured in UV continuum. The compact physical size seems to be the critical determining factor in whether a galaxy will show lyman-alpha emission.

407.04

SED Fitting with Markov Chain Monte Carlo: The Case of z=2.1 Lyman Alpha Emitters Viviana Acquaviva¹, L. Guaita², E. Gawiser¹, N. Padilla² ¹*Rutgers, The State University of New Jersey,* ²*Universidad Catolica de Chile, Chile.* 10:30 AM - 10:40 AM

Room 608

The analysis of Spectral Energy Distributions (SEDs) of faraway galaxies provides us with valuable information on how the structures in the Universe evolved into what we see today. This requires a correct interpretation of data which are constantly improving in volume and precision, which can only be done by developing adequately sophisticated instruments of statistical analysis. We present our Markov Chain Monte Carlo (MCMC) algorithm, which is able to sample large parameter spaces and complicated star formation histories efficiently and can handle multiple stellar populations. This instrument is key for obtaining reliable estimates of SED parameters (e.g. age, stellar mass, dust content) and their uncertainties. It also reveals degeneracies between parameters and illustrates which physical quantities are best suited to describe certain samples of galaxies. We apply this method to the sample of 250 z = 2.1 Lyman Alpha Emitters (LAEs) from Guaita et al (2010a). High-redshift LAEs are of great interest because they probe the faint end of the galaxy luminosity function, where the bulk of galaxies reside, and have been shown to be building blocks of Milky-Way type galaxies today. This analysis complements the ones presented for z=3.1 LAEs in Gawiser et al (2007) and for a number of subsamples of the same z=2.1 LAE sample in Guaita et al (2010b), which were carried out using a gridbased maximum likelihood method. Our results confirm and strengthen the findings that LAEs at z = 2.1 have similar stellar masses to, but are dustier than, z=3.1 LAEs; typical values are respectively M* ~ $5*10^8$ M_{sun} and A_v ~ 0.9. The current data don't allow us to discriminate among different star formation histories. We gratefully acknowledge support from NSF, DOE and NASA.

407.05

Resolved Images of Escaping Lyman Continuum Emission from z=3 Galaxies

Brian D. Siana¹, A. E. Shapley², C. C. Steidel¹, H. I. Teplitz³ ¹Caltech, ²UCLA, ³IPAC/Caltech.

10:40 AM - 10:50 AM

Room 608

In order for star-forming galaxies to reionize the intergalactic medium (IGM) at z > 6, a significant fraction of the ionizing photons must escape into the IGM. Recently, a subset of galaxies at z=3.1 have been found emitting ionizing radiation, but it is unclear why these galaxies have such large escape fractions. To better understand the mechanisms which allow for large escape fractions, we have obtained a single, 32-orbit image with the WFC3/UVIS camera on HST to obtain resolved images of escaping Lyman continuum (LyC) radiation from 10 galaxies at z~3.1. Seven galaxies are detected with leaking LyC. In many of the galaxies, the LyC flux is only coming from a subset of the star-forming regions. We will present the LyC morphologies, resolved SEDs of the LyC-emitting regions, and rest-frame UV spectra of these galaxies. Together, these data will help us understand how galaxies were able to reionize the universe and subsequently maintain the ionizing background at high redshift.

407.06

NOMADS : Physical Origins And Conditions Of Line-emitting Gas From High-redshift (1 < z < 3) Galaxies Shelley Wright¹, C. Ma¹, J. Larkin², J. Graham³

¹UC, Berkeley, ²UC, Los Angeles, ³Dunlap Institute for Astronomy & Astrophysics, Canada. 10:50 AM - 11:00 AM

Room 608

We present results from NOMADS (Near-infrared OSIRIS Metallicity, AGN, and Dynamics Survey) of spatially resolved rest-frame optical emission lines (e.g., H β , [O III], H α , and [N II]) for nine star forming galaxies at a redshift range of 1 < z < 3. These results are part of an on-going survey to study the chemical abundances, dynamics, and role of weak active galactic nuclei (AGN) in galaxies that have been used previously in metallicity studies at high-redshift. Using 0.1" spatial scale with the integral field

spectrograph OSIRIS coupled to the Keck Adaptive Optics system we can identify, localize, and quantify any contribution from AGN activity in these measurements and map two-dimensional chemical abundances on sub-kiloparsec scales. We present metallicity gradients and kinematics for several high-z galaxies and place constraints on the formation mechanisms of these young, star forming galaxies. In addition, we find that a few of these systems do harbor weak non-thermal activity and we will discuss the role of AGN in galaxy formation. We acknowledge funding support from NASA STScI HF-51265.01.

407.07

A New Population Of High-EW Emission-Line Galaxies In The WISP Survey

Hakim Atek¹, B. Siana², M. Malkan³, P. McCarthy⁴, H. I. Teplitz⁵, C. Scarlata¹ ¹SSC - Caltech, ²Caltech, ³UCLA, ⁴Carnegie Observatories, ⁵IPAC - Caltech. 11:00 AM - 11:10 AM

11:00 AIVI - 11:10

Room 608

The WFC3 Infrared Spectroscopic Parallel (WISP) survey is an ongoing large (> 500 orbits) HST pure parallel program to obtain slitless, near-infrared spectroscopy of ~ 200 independent, high-latitude fields using the Wide Field Camera-3 grisms. The survey will ultimately provide an unbiased sample of thousands of emission-line and continuum-selected objects, that will enable an accurate measurement of the star formation history over the last 10 billion years, a better characterization of the properties (star formation rates, metallicities, dust extinction) of galaxies at the epoch of peak star formation rate density, and possibly the serendipitous discovery of highly luminous z>6.5 Lya emitters. I will discuss a new population of high-EW emission-line galaxies that we discovered in the 0.5<z<2.5 redshift range and the implications of such bright nebular lines on high-z studies. We also obtained follow-up Keck spectroscopy for a subset of galaxies that reveals extremely low metallicity systems and different rest-frame UV properties.

407.08

Passive Galaxies In The Wisp Survey

Claudia Scarlata¹, P. McCarthy², M. Malkan³, H. Teplitz⁴, H. Atek⁵, J. Colbert⁵, B. Siana⁶ ¹University of Minnesota, ²Carnegie, ³UCLA, ⁴IPAC, ⁵SSC, ⁶Caltech. 11:10 AM - 11:20 AM

Room 608

The WFC3 Infrared Spectroscopic Parallel (WISP) survey consist of ~400 orbits of HST pure parallel observations with the WFC3 G102 and G141 infrared grisms. The broad, continuous, spectral coverage (between 0.8 and 1.7um) provides the best currently feasible Halpha-based measurement of the star formation rate, in the 0.5<z<1.7 redshift range. The high sensitivity of the WISP survey leads also to a wealth of information from continuum spectra. The 4000AA break and the convergence of the Balmer series at 3650AA, provide two of the best low-resolution diagnostics for redshift and stellar populations. Continuum spectral diagnostics, particularly at z >1, provide constraints on the mean age of the stellar population and the time since the last major episode of star formation. I will present the spectroscopic analysis of a sample of galaxies at z~2, preselected to have colors consistent with passive galaxies at z~1.5. I will discuss their sizes, and morphological properties derived from the J and H WFC3 images we are obtaining as part of the WISP survey.

407.09

First Constraints on the Metallicities of High-Redshift Lyman Alpha Galaxies

Steven L. Finkelstein¹, K. Gebhardt², G. Hill², J. Adams², G. Blanc², C. Papovich¹, E. Gawiser³, N. Drory⁴ ¹*Texas A&M University,* ²*University of Texas,* ³*Rutgers University,* ⁴*Max Planck Institute for Extraterrestrial Physics, Germany.* 11:20 AM - 11:30 AM

Room 608

We present the results of Keck/NIRSPEC spectroscopic observations of two Lyman alpha emitting galaxies (LAEs) at z = 2.3 and 2.5 discovered with the HETDEX pilot survey. We detect Halpha, [OIII], and Hbeta emission, representing the first detection of multiple rest-frame optical emission lines in highredshift LAEs. We find that the systemic redshifts of these galaxies are different from that of the Lyman alpha emission by ~ 100-150 km/s, implying a large-scale outflow may be occurring in the interstellar medium of these galaxies. These outflows are likely powered by star-formation activity, as examining these LAEs in a line-ratio diagnostic plane implies that neither hosts an active galactic nucleus. We place the first meaningful constraints on the gas-phase metallicities in LAEs by using the upper limits on the [NII] emission, finding Z < 0.2 and < 0.3 Zsol in these two LAEs. Measuring the stellar masses of these objects (~ 10^{10} and 10^{9} Msol, respectively), we study the nature of LAEs in a mass-metallicity plane. These LAEs appear to be more metal poor than Lyman Break galaxies at the same redshift, implying that objects exhibiting Lyman alpha emission may be systematically less chemically enriched than the general galaxy population at similar redshifts. Lastly, neglecting the contribution of the measured emission line fluxes when fitting models to the observed photometry can result in overestimates of the stellar population age by orders of magnitude, and stellar mass by a factor of ~ 3. This is particularly important at very high redshift, where strong emission lines may masquerade in the photometry as a 4000 A break.

408

AGN, QSO, Blazars VII Oral Session Room 607

408.01

The Exceptional Flaring Activity Of The Blazar 3C 454.3

Erin Wells Bonning¹, C. Bailyn¹, M. Buxton¹, R. Chatterjee¹, P. Coppi¹, G. Fossati², J. Isler¹, L. Maraschi³, C. Urry¹

¹Yale University, ²Rice University, ³INAF/Brera, Italy.

10:00 AM - 10:10 AM

Room 607

The blazar 3C 454.3 has been in an historically active state for the last several years. Since the launch of the Fermi Gamma ray Space Telescope, the blazar has undergone several flaring episodes, becoming the brightest persistent source in the gamma ray sky in December 2009. We have carried out an optical and near-IR monitoring campaign on 3C 454.3, observing the source with a near-nightly cadence since August 2008. We correlate the optical and near-IR fluxes with the Fermi gamma-ray data as well as optical, UV, and X-ray fluxes from Swift Target of Opportunity observations during exceptionally high flux states. Since optical and IR fluxes are well-correlated with the gamma-rays, we can extrapolate to zero gamma-ray flux, revealing optical/IR magnitudes which can be associated with the underlying thermal accretion disk. This allows the thermal disk component to be disentangled from the jet synchtrotron component, allowing the variability properties of the jet to be more precisely studied. We present the results of our multiwavelength campaign, comparing the August 2008 flare with the November-December 2009 flare. We find a strong change in variability characteristics which will be discussed in terms of jet emission models.

408.02

Coordinated Multiwavelength Observations of PKS 0528+134 in Quiescence Markus Boettcher¹, N. Palma¹ ¹*Ohio Univ..* 10:10 AM - 10:20 AM

Room 607

We report results of an intensive multiwavelength campaign on the prominent high-redshift (z = 2.06) gamma-ray bright blazar PKS 0528+134 in September - October 2009. The campaign was centered on four ~ 30 ksec pointings with XMM-Newton, supplemented with ground-based optical (MDM, Perkins) and radio (UMRAO, Medicina, Metsaehovi, Noto, SMA) observations as well as long-term X-ray monitoring with RXTE and gamma-ray monitoring by Fermi. We find significant variability on ~ 1 day time scales in the optical regime, accompanied by a weak redder-when-brighter trend. X-ray variability is found on longer (~ 1 week) time scales, while the Fermi light curve shows no evidence for variability, neither in flux nor spectral index. We constructed four simultaneous spectral energy distributions, which can all be fit satisfactorily with a one-zone leptonic jet model.

This work was supported by NASA through XMM-Newton Guest Observer Grant NNX09AV45G.

408.03D

Variability in Active Galactic Nuclei Carolin Villforth¹

¹STScl. 10:20 AM - 10:40 AM *Room 607* Variability is a propert

Variability is a property shared by practically all AGN. As the centers of AGN cannot be resolved on most wavelength, variability studies can be used to infer important information about the physical conditions in the centers of AGN. In this dissertation talk, I will discuss what optical polarization data can reveal about the properties of blazar jets and how variability selection can be used as an efficient technique for finding AGN.

408.04

A Gamma-Ray Outburst in the Quasar 4C+21.35 on Milliarcsecond Scale

Svetlana G. Jorstad¹, A. P. Marscher¹, P. S. Smith², V. M. Larionov³, I. Agudo¹, A. Lahteenmaki⁴ ¹IAR, Boston Univ., ²Steward Observatory, Univ. of Arizona, ³St.Petersburg State Univ., Russian Federation, ⁴Metsahovi Radio Obs., Finland.

10:40 AM - 10:50 AM

Room 607

We analyse a strong gamma-ray outburst of the quasar 4C+21.35 that started in the end of September 2009, reached a maximum in June 2010 when the quasar was the brightest source in the gamma-ray sky, and died in 2010 August. We monitor the quasar with the VLBA at 43 GHz, the 13 m telescope of Metsahovi Radio Obs. at 37 GHz, and several optical telescopes that possess photometric and polarimetric capabilities. We have found a statistically significant correlation between the gamma-ray/optical and gamma-ray/radio light curves as well as an increase of linear polarization from <1% to 6.5% during the high gamma-ray state along with a rotation of the optical polarization position angle by ~200 degrees. We discuss the observed behavior within the context of a similar pattern reported previously in BL Lac, PKS 1510-089, and 3C 279. Our findings suggest multiple-zone locations of high energy emission in blazar jets that spread from the broad line region to the mm-wave VLBI core. The research at BU was funded in part by NASA Fermi Guest Investigator grants NNX08AV65G and NNX09AT99G and by NSF grant AST-0907893. The VLBA is an instrument of the National Radio Astronomy Observatory, a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

408.05 Highlights Of The Blazar Program With The Veritas Gamma-ray Observatory Lucy Fortson¹, VERITAS

¹University of Minnesota.

10:50 AM - 11:00 AM

Room 607

VERITAS is a state-of-the-art ground-based gamma-ray observatory located near Tucson, Arizona. Utilizing an array of four 12-m telescopes, VERITAS detects Cherenkov light from gamma-ray airshowers and is currently the most sensitive Very High Energy (E>100 GeV) gamma-ray observatory in the world. The VERITAS Blazar Program is entering its fourth year with 19 blazars detected including ten discoveries. Among these are four Intermediate-frequency peaked BL-Lac (IBL) objects. Results of the VERITAS blazar program will be highlighted in this presentation including summaries on recent multiwavelength campaigns as well as the impact that the Fermi Satellite data has had on the blazar observing program. Long-term light curves of bright blazars, including Mrk 421, reveal significant flux variability, with the broadband spectral energy distributions (SEDs) from the growing number of VHE gamma-ray detected blazars providing constraints to competing emission models.

408.06D

The Megamaser Cosmology Project: Angular-Diameter Distances to Megamaser Galaxies and their Black Hole Masses

Cheng-Yu Kuo¹, J. A. Braatz², F. K. Lo², J. J. Condon², C. V. M. Impellizzeri², Megamaser Cosmology team ¹University of Virginia, ²National Radio Astronomy Observatory.

11:00 AM - 11:20 AM

Room 607

The Megamaser Cosmology Project (MCP) aims to measure the Hubble constant (H₀) to 3% accuracy in order to constrain the Dark Energy equation of state parameter, *w*. The key to achieving this goal is to measure distances accurately to galaxies well into the Hubble flow (50 - 200 Mpc). To measure accurate distances, we adopt the proven H₂O megamaser method pioneered by the study of NGC 4258. An essential component of this technique involves sub-milliarcsecon Very Long Baseline Interferometry (VLBI) imaging of the sub-parsec H₂O megamaser disks at the centers of active galaxies. We determine accurate angular-diameter distances to these galaxies with precise astrometry and kinematics of the maser clumps in the disks. For distance determination, we have concentrated mainly on six galaxies (UGC 3789, Mrk 1419, NGC 6264, NGC 6323, NGC 2273, and NGC 1194) that show the necessary maser spectral characteristics. In addition, we are pursuing VLBI imaging for several other galaxies for which a distance measurement would be difficult, but we can still measure masses of the black holes (BH) at their centers. In this talk, I will present our latest work on distance determination for NGC 6323 and NGC 6264, and our results on BH mass measurements for seven megamaser galaxies, along with implications for the universality of the M-sigma relation.

408.07

Kinematics of the Active Radio Source at The Nucleus of NGC1275 (3C84)

Kenneth I. Kellermann¹, MOJAVE Collaboration

¹NRAO. 11:20 AM - 11:30 AM

Room 607

NGC1275 (3C84) was one of the earliest known radio galaxies and is also the site of moderately strong and variable gamma-ray emission. For the past 15 years we have used the VLBA at 2 cm wavelength to follow the internal motions in this AGN. Previously we used European and US antennas at 2.8 cm to

extend our kinematic study as far back as the early 1970s. Combining these data sets shows a systematic motion of a southern feature receding from the core at 0.28 ± 0.04 mas/yr or v/c = 0.32 ± 0.05 , while the more slowly moving northern feature is moving at 0.10 ± 0.02 mas/yr or v/c = 0.11 ± 0.02 . The calculated ejection time of the southern feature occurred in the mid 1950s close to the start of the large centimeter radio outburst first observed at the UMRAO. From the observed motions, we find an intrinsic velocity of 0.5c at an angle of 20 degrees to the line of sight. The corresponding Lorentz factor is only 1.2 with Doppler factors of 1.6 and 0.6 for the approaching and receding features respectfully. Thus Doppler boosting is small, and so the intrinsic luminosity is close to the observed value of 10^{26} W/Hz. It is not clear how the this mildly relativistic jet of this powerful radio and gamma-ray galaxy fits into the broader picture of ultrarelativistic jets feeding the powerful radio lobes, unless the radio observations refer to a relatively slowly moving outer jet surrounding a faster inner spine whose directed radio emission is beamed away from the observer.

409

Star Associations, Star Clusters II Oral Session *Room 606*

409.01

Towards Producing Star Clusters in Galaxy Formation Simulations

Gregory S. Stinson¹, C. Brook¹, B. Gibson¹

¹University of Central Lancashire, United Kingdom.

10:00 AM - 10:10 AM

Room 606

Recent smoothed particle hydrodynamic (SPH) simulations have shown that it is possible to produce bulgeless dwarf galaxies. The result depends upon allowing gas to reach high densities before it can form stars. This is enabled by the use of unprecedented resolution in simulations of entire galaxies. One additional result of this change is that gas collapses into molecular clouds and forms stellar clusters. We compare the mass function of these clusters with observations and investigate the reality of the physics involved in these simulations.

409.02D

The Nature of the [O III] Emission Source in Black Hole Host Globular Cluster RZ2109

Matthew M. Steele¹, S. E. Zepf¹, A. Kundu², T. J. Maccarone³, K. L. Rhode⁴, J. J. Salzer⁴ ¹*Michigan State University*, ²*Eureka Scientific*, ³*University of Southampton*, *United Kingdom*, ⁴*Indiana University*.

10:10 AM - 10:30 AM

Room 606

The globular cluster RZ2109 located in NGC4472 was the first unambiguous identification of a black hole x-ray source in a globular cluster. Optical spectroscopy of RZ2109 display 3000 km s⁻¹ [O III] $\lambda\lambda$ 4959,5007 line along with the stellar spectra of the host globular cluster. Notably, the observed spectrum lacks measurable emission from any other atomic species. In this talk we present a multifacility study of the low to moderate resolution (R ~ 400-2400) optical spectra of RZ2109 with observations spanning 467 days. We focus on the [O III] λ 5007 line velocity profile and variability along with the lower limit on the [O III] λ 5007/H β ratio. We then consider possible models for the nature and geometry of emission line region. Finally we describe the ongoing search for additional broad emission line systems in x-ray binary hosting globular clusters.

MMS and SEZ wish to acknowledge support from NSF grants AST-0406891 and AST-0807557.

409.03

X-Ray Luminous Black Holes in Globular Clusters

Arunav Kundu¹, T. J. Maccarone², S. E. Zepf³, K. L. Rhode⁴, I. C. Shih⁵, T. D. Joseph² ¹Eureka Scientific, ²Univ. of Southampton, United Kingdom, ³Michigan State Univ., ⁴Indiana Univ., ⁵National Tsing Hua University, Taiwan.

10:30 AM - 10:40 AM

Room 606

Globular clusters are the smallest gravitationally bound stellar systems in the universe. There has long been an interest in detecting black holes in globular clusters and studying its implications. Accreting X-ray luminous systems can provide some of the most direct evidence of black holes in globular clusters. We present the results of our ongoing multiwavelength search for black holes in the globular cluster systems of nearby elliptical and SO galaxies. We have established the presence of black holes in multiple extragalactic globular clusters through X-ray variability and luminosity. We discuss the implications of our results on the formation and retention of black holes in clusters.

409.04D

The M31 Globular Cluster System and its X-ray Binaries Mark Peacock¹

¹*Michigan State University.*

10:40 AM - 11:00 AM

Room 606

M31 hosts the largest and possibly most diverse cluster population in our local group. Its proximity to us makes it an important bridge between the well studied clusters in the Milky Way and the more distant, but often more numerous and diverse, extragalactic cluster systems. We have undertaken a large, multiwavelength, survey of these clusters to investigate their properties. In this talk, I'll present the highlights of this study including the photometric and structural properties of these clusters. I'll also discuss the properties of clusters that are found to host X-ray binaries. From this work, I'll show correlations between the formation of X-ray binaries and the metallicity, mass and stellar collision rate of their host clusters. In particular, I'll demonstrate that stellar interactions appear to be the dominant factor in the formation of X-ray binaries in M31's clusters, consistent with the dynamical formation of these systems.

409.05

Highlights from the Chandra Carina Complex Project: Connecting X-ray and Mid-Infrared Observations of the Great Nebula in Carina

Matthew S. Povich¹, L. K. Townsley¹, P. S. Broos¹, N. Smith², S. R. Majewski³ ¹Penn State University, ²University of Arizona, ³University of Virginia. 11:00 AM - 11:10 AM

Room 606

The Chandra Carina Complex Project (CCCP) obtained a 1.2-Ms total integration covering a 1.42 square degree field of the Great Nebula in Carina. Combining the 14,368 X-ray sources from the CCCP catalog with mid-infrared (mid-IR) photometry from the Spitzer Vela--Carina Survey reveals the global properties of the intermediate- (2-8 Msun) and high-mass (>8 Msun) young stellar population in unprecedented detail. We identify 94 new candidate X-ray emitting OB stars, potentially doubling the size of the known young massive stellar population in this marquee H II region. We use mid-IR excess emission to catalog 1439 young stellar objects (YSOs) throughout the Carina Nebula, 410 of which have counterparts in the CCCP X-ray catalog. The global SFR in the Carina Nebula, averaged over the past ~5 Myr, has been approximately constant. While much of the ongoing star formation has migrated to the

outer regions of the nebula, perhaps driven by feedback from OB stars, the massive ionizing clusters Tr 16 and Tr 14 remain hotbeds of recent star formation, each hosting large populations of intermediatemass YSOs. Our results indicate that intermediate-mass YSOs produce X-rays during their early pre-main sequence evolution, perhaps driven by magnetic dynamo activity during the convective atmosphere phase, but this emission dies off as the stars approach the main sequence. This finding is in stark contrast to the well-established evolution of X-ray emission observed from low-mass T Tauri stars, for which the X-ray luminosity increases as the stars evolve toward the zero-age main sequence. M.S.P. is supported by an NSF Astronomy and Astrophysics Postdoctoral Fellowship under award AST-0901646.

410

Supernovae III Oral Session Room 613/614

410.01

Solutions for Successful Core Collapse Superonva Explosions by the Neutrino Mechanism Jeremiah Wayne Murphy $^{\rm 1}$

¹University of Washington. 10:00 AM - 10:10 AM Room 613/614

Core-collapse supernovae are some of the most energetic events in the Universe; they herald the birth of neutron stars and black holes, are a major site for nucleosynthesis, influence galactic hydrodynamics, trigger further star formation, and are prodigious emitters of neutrinos and gravitational waves. As such, it is important to understand the mechanism of explosion. Yet, the details of the mechanism have remained elusive for many decades. For nearly four decades, the preferred mechanism for successful explosions has been the delayed-neutrino mechanism, in which a neutrino luminosity of a few times 10^{52} erg/s revives the failed shock wave. While 1D radiation-hydrodynamic simulations fail to produce explosions, 2D simulations show promise. We investigated the conditions and criteria necessary for supernova explosions by the neutrino mechanism and found that the critical neutrino luminosity for explosion for 2D simulations is ~70% of the critical luminosity for 1D simulations. Our initial investigations suggested that understanding the role of convection and other nonradial instabilities would be key to explaining the reduction in the critical luminosity. Adapting recent developments in turbulence theory to the specific context of core collapse, we are developing a model for core-collapse explosions that explains the reduction in the critical luminosity.

410.02D

Exploring the Generation of Magnetic Fields by the Stationary Accretion Shock Instability with GenASiS

Reuben Budiardja¹, E. Endeve², C. Cardall¹, A. Mezzacappa² ¹Univ. of Tennessee, ²Oak Ridge National Laboratory. 10:10 AM - 10:30 AM Room 613/614

We are developing GenASiS (General Astrophysical Simulation System) to study the explosion mechanism of core-collapse supernovae. The current version of GenASiS is suitable for large scale simulations and includes a mature implementation of magnetohydrodynamics as well as a general Poisson solver. As a science application of the code, we explore the capacity of the stationary accretion shock instability (SASI) in the post-bounce supernova environment to generate magnetic fields by adding a weak magnetic field to an initially spherical symmetric fluid configuration that models an idealized

stalled supernova shock. We find that the SASI flows generate a significant boost of the magnetic energy. Implications for the magnetization of neutron stars are considered.

410.03

The Unusual Supernova 1978K and Dust Formation Schuyler D. Van \mbox{Dyk}^1

¹Spitzer Science Center/Caltech. 10:30 AM - 10:40 AM Room 613/614

We cannot yet explain why galaxies at high redshift, early in the history of the Universe, show appreciable dust content. Various models have introduced the possibility that core-collapse supernovae (SNe) from early stars may be the main contributors of the dust. Recently, particularly with the Spitzer Space Telescope, several investigations have attempted to determine whether or not SNe, based on nearby events, produce enough dust to match the model predictions. So far, the results have not been promising, but the SNe have generally been from relatively low-mass progenitors. Analysis of the dust content in the young Galactic supernova remnant Cas A, which may have had a high-mass progenitor, has indicated that possibly enough dust has been freshly formed to be in agreement with the lower limits of these models. This indicates potentially that SNe from high-mass stars could be adequate dust producers. The unusual, nearby SN 1978K in NGC 1313 is another excellent case to examine for dust production, since many indicators point to this SN having had a very massive stellar progenitor. SN 1978K has been observed with Spitzer with all cryogenic instruments, and here we present our data analysis, particularly of the IRS spectra, and estimate the dust properties and mass associated with this object.

410.04

Quantifying Neutron Star Spins from Spiral SASI Modes Rodrigo $\mbox{Fernandez}^1$

¹Institute for Advanced Study. 10:40 AM - 10:50 AM *Room 613/614*

The stalled accretion shock in core-collapse supernovae is unstable to non-spherical perturbations. In three-dimensions, this instability can develop spiral modes that torque the nascent neutron star. I'll report work that quantifies the angular momentum redistribution caused by these modes, and the feasibility of their excitation. Maximum spin periods of the order of 60ms can be obtained out of a non-rotating progenitor. The bulk of the angular momentum redistribution occurs during the exponential growth of unstable modes, and operates through non-oscillatory torques that are second order in the peturbation amplitude.

410.05

Observational Constraints on Clumpiness in Supernova Ejecta

K. Tabetha Hole¹, C. Boom²

¹ETSU, ²Weber State University. 10:50 AM - 11:00 AM

Room 613/614

Observations of polarization in supernovae (SNe) at early times have indicated the presence of asymmetries that vary in both magnitude and orientation for different elements in the ejecta. One explanation for these observations is local chemical inhomogeneities ("clumps") in the ejecta above the region which forms the continuum. To understand the effects of clumpiness on spectropolarimetric observations, we have used a fast, flexible, approximate semi-analytic code for modeling polarized line

radiative transfer within three-dimensional inhomogeneous rapidly expanding atmospheres to model a wide range of clump parameter space. The results of the model make predictions that constrain the size and number of clumps that could lead to a given polarimetric signature. This talk will present a test of the model and the resulting predictions for VLT spectropolarimetric observations of SN2006X. This project was funded by the National Science Foundation grant AST-0807664 and through the Research Experiences for Undergraduates (REU) program grant NSF AST-1004872.

411

The Role of Environment in Galactic Star Formation Oral Session *Room 604*

411.01

A Spitzer Comparison of Protostellar Luminosity Functions Across Diverse Star Forming Enviornments Erin Kryukova¹, S. Megeath¹

¹University of Toledo. 10:00 AM - 10:10 AM Room 604

We approach the fundamental question "How does environment affect star formation and the properties of nascent stars?" by comparing populations of protostars in diverse environments. In our study, we present a sample of over 900 Spitzer-identified protostars from the nearby (within 1 kpc) star forming clouds Orion A & B, Cep OB3, Serpens, Perseus, Ophiuchus, Taurus, Lupus, Chamaeleon, and Mon R2, and the more distant massive star forming region Cyg X (at 1700 pc); these encompass a range of cloud environments including regions of clustered and isolated star formation and regions of low and high mass star formation. Using Spitzer 3 to 24 micron photometry combined with 2MASS J, H, and K photometry we calculate SED slope and mid-IR luminosities for each of our protostars. We then use a sample of c2d protostars with known bolometric luminosities to create an empirical mid-IR/bolometric luminosity relationship, and determine bolometric luminosities for our protostars. Luminosity functions are then created for each cloud and corrected for contamination due to background galaxies, edge-on Class II YSOs, and reddened Class II YSOs. In each cloud, the luminosity function peaks near 1 Lsun, and in the more massive clouds that form higher mass stars, the luminosity functions show a tail extending up towards 1000 Lsun. We compare the luminosity functions in the different clouds and identify significant differences between the functions in different clouds, demonstrating that the luminosity function depends on the host cloud. We examine luminosity functions as a function of the surrounding density of young stars, and find that in Orion and Cyg X, and to some extent Ophiuchus, the luminosity functions of protostars in dense environments are statistically different than those in more isolated environments, with the luminosity function in dense environments in Orion and Cyg X extending to higher luminosities.

411.02

Clarifying Our View of Milky Way Massive Young Star Clusters with Adaptive Optics Jessica R. Lu¹, A. M. Ghez², N. McCrady³, S. Yelda² ¹Caltech, ²UCLA, ³University of Montana, Missoula.

10:10 AM - 10:20 AM

Room 604

We present Keck laser guide star adaptive optics (AO) observations of the massive young star clusters W51 G48.9-0.3 and W49A Cluster 1 in an effort to test the universality of the initial mass function (IMF) in extreme star forming environments. High-precision AO astrometry over a 1 year time baseline is successfully used to separate cluster members from contaminating field objects with differential proper

motions as small as ~0.5 mas/yr (15 km/s at 6 pc). We have developed improved AO photometric analysis techniques and use the near-infrared photometry of the proper motion selected cluster members to construct mass functions corrected for spatially varying extinction and incompleteness. Contrary to previous results for W51, we measure a mass function that has a high-mass end slope consistent with a Salpeter IMF and find that the observed cluster mass within 0.3 pc is <700 solar masses between 1 and 60 solar masses.

411.03D

$\text{HCO}^{\scriptscriptstyle +}$ and $N_2\text{H}^{\scriptscriptstyle +}$ Spectroscopy of Sources in the Bolocam Galactic Plane Survey

Wayne M. Schlingman¹, Y. L. Shirley¹, J. Bally², C. Battersby², D. E. Bolin¹, M. K. Dunham³, T. Ellsworth-Bowers², N. J. Evans, II⁴, A. Ginsburg², E. Rosolowsky⁵, G. S. Stringfellow²

¹Univ. of Arizona, ²Univ. of Colorado, ³Yale University, ⁴Univ. of Texas, ⁵Univ. of British Columbia, Okanagan.

10:20 AM - 10:40 AM

Room 604

We present the results of observations of 1882 sources in the Bolocam Galactic Plane Survey (BGPS) at 1.1mm with the 10m Heinrich Hertz Telescope simultaneously in $HCO^+ J = 3 - 2$ and $N_2H^+ J = 3 - 2$. We detect 77% of these sources in HCO^+ and 51% in N_2H^+ . We find a strong correlation between both dense gas tracers and the 1.1 mm dust emission of BGPS sources. We determine kinematic distances and break the distance ambiguity for 435 sources for which we derive the size, mass, and average density. The median size of BGPS clumps is 0.86 pc with a median mass of 330 M_{sun}. The median HCO^+ linewidth is 3.1 km/s indicating that BGPS clumps are dominated by supersonic turbulence or unresolved kinematic motions. We find no evidence for a size-linewidth relationship for BGPS clumps. We analyze the effects of the assumed dust temperature on the derived clump properties with a Monte Carlo simulation. The observed differential mass histogram has a power-law slope that is intermediate between that observed for diffuse CO clouds and the stellar IMF. BGPS clumps represent a wide range of objects (from dense cores to more diffuse clumps) and are typically characterized by larger sizes and lower densities than previous published surveys of high-mass star forming regions. This collection of objects is a less-biased sample of star forming regions in the Milky Way that likely span a wide range of evolutionary states.

411.04

Molecular Kinematics Tracers in Bright-Rimmed Cloud SFO14

Charles C. Figura¹, L. Morgan², T. Moore², J. Urquhart³

¹Wartburg College, ²Liverpool John Moores University (Astrophysical Research Institute), United Kingdom, ³Australia Telescope National Facility, Australia.

10:40 AM - 10:50 AM

Room 604

The star cluster AFGL4029 and associated nebulosity IC1848 (herein referred to as bright-rimmed cloud SFO14) has been forwarded by numerous studies as an example of small-scale sequential star formation (S4F), in which star formation proceeds across a region as the result of triggering mechanisms such as Collect-and-Collapse and Radiative Driven Implosion (RDI). We would like to develop a detailed picture of the molecular dynamical interactions within SFO14 (and other regions where RDI may be responsible for star formation) in order to see if the dynamics within the cloud can be linked to the conditions in the HII region beyond the rim.

We present multi-wavelength observations of the bright-rimmed cloud SFO14 in $NH_3(1,1)$ and (2,2) inversion transitions and ^{12}CO , ^{13}CO , and $C^{18}O$ (J=3->2) transitions. These observations allow determination of kinematics within the cloud (thermal and turbulent motions and outflows), cloud opacities, and kinetic temperatures.

We identify two cores within SFO14: a larger primary core nearer the rim (associated with the known UCHII reigion AFGL4029-IRS1) and a weaker core approximately 2' east of the primary. These cores are apparent in both NH_3 and CO maps, although positions of peak molecular emission vary by about 20". The primary core shows morphological evidence of interaction with the rim in both NH_3 and CO species. These CO and NH_3 observations combine with earlier observations (including 8 μ m and radio emission maps) to make SFO14 one of the more convincing examples of RDI-triggered star formation. Extending these studies to a larger sample of bright-rimmed clouds is expected to verify the role of RDI as a significant contributor to the galactic IMF.

411.05

Cold Cores Identified at 160 microns in the Taurus Spitzer Survey

S. Terebey¹, M. Fich², A. Noriega-Crespo³, D. L. Padgett³, Taurus Spitzer Legacy Team ¹Cal. State Univ. at Los Angeles, ²Univ Waterloo, Canada, ³Caltech. 10:50 AM - 11:00 AM

Room 604

We have developed a technique to identify cold cores in star-forming regions using 160 micron image data from the Spitzer Space Telescope in combination with 100 micron IRAS data. The method is applied to the 44 square degree Taurus Legacy Survey to produce an image of emission from cold cores, and further produce a catalog of cores covering the entire Taurus region. The 160 micron cold cores are an excellent tracer of dense gas and dust, and correlate well with high extinction (Av > 4) and submillimeter continuum emission. Comparing the distribution of known YSOs and new YSO candidates with the cold cores we find most class I sources are spatially coincident with a cold core. However, most 160 micron cold cores in Taurus are starless. We discuss some of the implications for cold core lifetimes.

411.06

An Observed Lack of Substructure in Starless Cores

Scott Schnee¹, M. Enoch², D. Johnstone³ ¹NRAO, ²UC Berkeley, ³NRC-HIA.

11:00 AM - 11:10 AM

Room 604

We present the results of a high resolution (5") Combined Array for Research in Millimeter-wave Astronomy and Sunyaev-Zeldovich Array survey of the 3 mm continuum emission from 11 of the brightest (at 1.1 mm) starless cores in the Perseus molecular cloud. We detect 2 of the 11 cores, both of which are composed of single structures, and the median 3 sigma upper limit for the non-detections is 0.2 Msun in a ~5" beam. From the non-detection of multiple components in any of the 11 cores, we conclude that starless core mass functions derived from bolometer maps at resolutions range 10"-30" are unlikely to be significantly biased by the blending of lower mass cores with small separations. We also present molecular line follow-up observations of one starless core and discuss the kinematics and chemistry of this core.

412 *Intergalactic Medium, QSO Absorption Line Systems* Oral Session *Room 609*

412.01D

Wavelength Calibration Errors in Keck-HIRES/VLT-UVES and Variation in the Fine-Structure Constant Jonathan Whitmore¹

¹University of California - San Diego.

10:00 AM - 10:20 AM

Room 609

There have been published results claiming that both the VLT-UVES and Keck-HIRES spectrographs have measured a change in the fine-structure constant (alpha) over cosmological timescales. These measurements rely on precise measurements of the relative spacing of QSO absorption lines. In an effort to provide an independent check on the accuracy of the standard thorium-argon wavelength calibration pipelines, we analyzed spectra of several QSO and star exposures taken with the iodine cell on each instrument. We developed a new method to use the iodine cell as a way to accurately probe distortions to the standard wavelength calibration across echelle orders. We found a couple of types of wavelength shifts needed to correct the Th/Ar wavelength scale in both instruments, and in particular we found shifts within echelle orders (intra-order) distortions that have the potential to affect the claimed detections. For VLT-UVES, we find intra-order velocity distortions of 100 m/s up to more than 200 m/s. These calibration errors are similar to, but smaller than, those found in the Keck-HIRES spectrometer (300 m/s up to 800 m/s). Using the results of Monte Carlo mock experiments, we find errors in the relative change in alpha of between 1e-6 Nsys^(-1/2) and 3e-6 Nsys^(-1/2), where Nsys is the number of systems used and the range is due to dependence on how many metallic absorption lines in each system are compared. We discuss the possible origins and further implications of these miscalibrations as a systematic error in the published claims of a measurement of a relative change in alpha (current value - past value) / current value. Finally, we possibly present results from recent attempts to provide a simple method to correct the miscalibrations in QSO exposures using a reference star exposure.

412.02

The Magellan/MagE Survey for Molecular Hydrogen in High-Redshift Galaxies Regina Jorgenson¹

¹Institute of Astrnomy, Cambridge, United Kingdom.

10:20 AM - 10:30 AM

Room 609

We present the results of the first unbiased, blind survey for Molecular Hydrogen (H2) in high redshift (z \sim 2-4) Damped Lyman alpha systems (DLAs). These are the most gas-rich quasar absorption systems and, since they contain the bulk of the neutral gas at high-z, may fuel star formation over much of the Hubble time. But despite H2 being the main molecular coolant and therefore an important ingredient for star formation, its covering fraction in DLAs is unknown, primarily because few H2-bearing DLAs have been found --mostly serendipitously -- and disproportionately high column density (N(HI)) systems have been searched. To better understand the link between DLAs and high-z star formation we measured the H2-bearing DLA fraction and H2 covering fraction by exploiting the excellent UV throughput of the Magellan/MagE spectrograph in a relatively fast, medium resolution survey of ~100 DLAs selected without N(HI) bias. We will present the results of this survey. This research is partially supported by the

STFC-funded Galaxy Formation and Evolution program at the Institute of Astronomy, University of Cambridge.

412.03D

Threshold Clustering Functions and Thermal Inhomogeneities in the Lyman-Alpha Forest Khee-Gan ${\rm Lee}^1$

¹Princeton University Observatory.

10:30 AM - 10:50 AM

Room 609

We introduce to astrophysics the threshold clustering function S2 first derived by Torquato et al. (1988), which effectively samples the flux probability distribution (PDF) of the Ly α forest at different spatial scales. These statistics are tested on mock Ly α forest spectra based on various toy models for He II reionization, with homogeneous models with various temperature-density relations as well as inhomogeneous models with temperature differences of ~10,000K and different equations of state T ~ $\Delta^{(\gamma-1)}$. These mock samples have systematics and noise added to simulate the latest Sloan Digital Sky Survey Data Release 7 (SDSS DR7) data. The traditional flux PDF is degenerate to temperature inhomogeneities in the IGM arising from He II reionization, but we find S2 can detect these inhomogeneities at ~5 σ , with the assumption that the flux continuum of the Ly α forest can be determined to 3% accuracy, then S2 is capable of constraining the characteristic scale of temperature inhomogeneities, with ~4 σ differentiation between toy models with hot bubble radii of 50 Mpc/h and 100 Mpc/h.

412.04D

The Incidence Of Cool Gas In 10¹³ m_O Halos

Jean-Rene Gauthier¹, H. Chen¹, J. Tinker²

¹University of Chicago, ²University of California, Berkeley.

10:50 AM - 11:10 AM

Room 609

We present the first results of an ongoing spectroscopic follow-up of close luminous red galaxies (LRGs) and MgII $\lambda\lambda$ 2796,2803 absorber pairs for an initial sample of 15 photometrically selected LRGs at physical projected separations $\rho \le 350 h^{-1}$ kpc from a QSO sight line. Our moderate-resolution spectra confirm a physical association between the cool gas ($T \sim 10^4$ K) revealed by the presence of MgII absorption features and the LRG halo in five cases. In addition, we report an empirical estimate of the maximum covering fraction (κ max) of cool gas in massive, $\sim 10^{13} h^{-1}$ M_{sun} dark matter halos hosting LRGs at $z \sim 0.5$. This study is performed using a sample of foreground LRGs that are located at $\rho < 400 h^{-1}$ kpc from a QSO sight line. The LRGs are selected to have a robust photometric redshift $\sigma z/(1+z_{ph}) \approx 0.03$.We determine κ max based on the incidence of MgII absorption systems that occur within $z_{ph} \pm 3 \sigma z$ in the spectra of the background QSOs. Despite the large uncertainties in z_{ph} , this experiment provides a conservative upper limit to the covering fraction of cool gas in the halos of LRGs. We find that κ max ≈ 0.07 at $Wr(2796) \ge 1.0$ Å and

 κ max ≈ 0.18 at $Wr(2796) \ge 0.5$ Å, averaged over 400 h^{-1} kpc radius. Our study shows that while cool gas is present in ~10¹³ h^{-1} M_{sun} halos, the mean covering fraction of strong absorbers is no more than 7%. J.-R.G. acknowledges support from the Brinson Foundation predoctoral fellowship and from the Sigma-Xi Grant-in-Aid of Research program. H.-W. C. acknowledges partial support from NASA grant NNG06GC36G and NSF grant AST-0607510.

412.05

Halo Gas and Galaxy Disk Kinematics of a Volume-Limited Sample of MgII Absorption Selected Galaxies at z~0.1

Glenn Kacprzak¹, C. W. Churchill², E. J. Barton³, J. Cooke¹

¹Swinburne University, Australia, ²New Mexico State University, ³UC Irvine.

11:10 AM - 11:20 AM

Room 609

MgII absorption lines detected in the spectra of background quasars allow us to probe the cool metalenriched halo gas associated with foreground galaxies. This technique allows us to directly study the complex halo gas which provides the fuel for star-forming disks. The dynamics of this gas is likely driven by one or more of the following physical processes: supernovae ejecta, stellar winds, minor mergers, and inflow via filaments or satellites. In an effort to gain an understanding of how halos are built and evolve in a cosmological context, we directly compare the MgII halo gas kinematics to the rotation velocities derived from emission/absorption lines of their host galaxies. Our volume-limited sample of 11 z=0.1 MgII absorption systems are associated with 13 galaxies located at projected distances of 12-90 kpc from the quasar line-of-sight. In half of our sample the MgII absorption reside to one side of the galaxy systemic velocity and aligns with one side of its rotation curve. In the remaining half, the absorption spans both sides of the galaxy systemic velocity, although the bulk of the MgII resides mostly to one side of the galaxy systemic velocity.

We find that extended disk-like rotation models fail to reproduce the MgII velocity spread in all but one case, implying additional dynamical processes (outflow/infall) must be invoked to explain the observed range of MgII absorption velocities. In addition, intrinsic host galaxy NaI and MgI absorption line ratios suggest that these galaxies do not host strong outflows, which is also consistent with their low star formation rates. These results provide strong evidence that the MgII absorbers are associated with the infalling gas which is fueling galaxy star formation.

413

Instrumentation: Ground Based Oral Session *Room 401*

413.01

EVLA Commissioning and Science Operations Status

Joseph P. McMullin¹, B. J. Butler¹, C. J. Chandler¹, B. C. Clark¹, V. Dhawan¹, R. L. Dickman¹, C. Langley¹, R. A. Perley¹, M. P. Rupen¹, K. Sowinski¹, J. M. Wrobel¹

¹NRAO. 10:00 AM - 10:10 AM *Room 401*

The Expanded Very Large Array (EVLA) project is an 11 year effort to radically improve key observational capabilities of the VLA (point source sensitivity, maximum BW, frequency resolution, number of channels, etc) while expanding to full frequency coverage between 1 and 50 GHz. Starting on March 1, 2010, simultaneous commissioning and science operations began with the upgraded system. We report on the status of the upgrades, the efforts to integrate the developing hardware and software components and the development of end-to-end observing capabilities which are regularly deployed to the community; the overarching philosphy has been to maximize the science capabilities of the system and their availability during the commissioning process. We show some of the recent scientific results through the ongoing shared-risk programs during the construction period. Finally, we review the

schedule through the end of the construction/commissioning period and the planned staging of new capabilities leading to full operations at the end 2012.

413.02

Optimization of Compact Array Configurations to Minimize Side-lobes for Two Cases: The LWA Phased-array Station and the New E-configuration for the EVLA

Leonid Kogan¹, F. Owen¹, J. Ott¹, A. Cohen²

¹National Radio Astronomy Observatory, ²The Johns Hopkins University Applied Physics Laboratory. 10:10 AM - 10:20 AM

Room 401

An optimization algorithm designed by Leonid Kogan (L. Kogan, Optimizing a Large Array Configuration to Minimize the Side lobes, IEEE Transactions on Antennas and Propagation, vol 48, NO 7, July 2000, p 1075) to minimize side-lobes in the point-spread response has been applied in the design of two new radio-interferometric arrays: (1) the most compact (E) configuration of EVLA and (2) the phased-array station for the Long Wavelength Array (LWA). Scientific programs for the EVLA's E-configuration includes galactic and Local HII, molecular gas, cosmic web, radio continum, radio lobes, SZ effect, cosmology and pulsar searches. The LWA will operate at frequencies from 10-88 MHz and will study a wide range of scientific programs including clusters of galaxies, high-redshift radio galaxies, pulsars, SNR's, extra-solar planets, solar physics and ionospheric physics. Both arrays need to be compact and to have the smallest side lobes possible. The E-configuration was designed to minimizes cost by requiring only one new railroad track in addition to the existing EVLA infrastructure. The shadowing factor achieved is reasonably good for a wide range of hour angles and declinations. The achieved side-lobe levels in the synthesized beam are no greater than 12% within the antenna primary beam for any operating VLA wavelength. For comparison, the VLA-D configuration has side-lobes near 60%. For the LWA station configuration, the sidelobes are never greater than 1.6% at any point in the sky regardless of phased direction or operating wavelength. Such small sidelobes for both arrays promise very high image fidelity for maximum scientific results.

413.03

An Update on the Long Wavelength Array

Gregory B. Taylor¹, S. E. Tremblay¹, Y. Pihlstrom¹, J. Craig¹, L. Rickard¹, J. Dowell¹, N. Kassim², T. Clarke², B. Hicks², E. Polisensky², P. Ray², H. Schmitt², D. Woods², J. Hartman², S. Ellingson³, C. Wolfe³, R. Navarro⁴, E. Sigman⁴, M. Soriano⁴, F. Owen⁵

¹Univ. of New Mexico, ²NRL, ³Virginia Tech, ⁴JPL, ⁵NRAO.

10:20 AM - 10:30 AM

Room 401

The Long Wavelength Array (LWA), a SKA Pathfinder, will be a new multi-purpose radio telescope operating in the frequency range 10-88 MHz. Scientific programs include pulsars, supernova remnants, general transient searches, radio recombination lines, solar and Jupiter bursts, investigations into the "dark ages" using redshifted hydrogen, and ionospheric phenomena. Upon completion, LWA will consist of 53 phased array "stations" distributed across a region over 400 km in diameter. Each station consists of 256 pairs of dipole-type antennas whose signals are formed into beams, with outputs transported to a central location for high-resolution aperture synthesis imaging. The resulting image sensitivity is estimated to be a few mJy (5sigma, 8 MHz, 2 polarizations, 1 h, zenith) from 20-80 MHz; with angular resolution of a few arcseconds. A technical overview of the LWA project is available (Ellingson etal. 2009, Proc. IEEE, 97, 1421), and additional information is online at http://lwa.unm.edu. Partners in the LWA project include LANL, JPL, NRAO, NRL, UNM, NMT, and Virginia Tech.

The first station of the LWA, called "LWA-1", is located near the center of the EVLA and is expected to

achieve initial operational capability in early 2011. As of September 2010, all antennas have been installed as well as a subset of the "production" versions of receivers, digital electronics, data recorders, and monitoring and control system. The "transient buffer - wideband" (TBW) capability is operational with 20 dipoles, and provides the ability to capture simultaneous raw 196 MSPS A/D output over the entire 10-88 MHz tuning range in 61 ms bursts. Other operating modes are in the final stages of implementation. Some early results obtained with LWA-1 will be presented. Funding for the LWA has been provided by the Office of Naval Research.

413.04D

Development Of A Multicolor Sub/millimeter Camera Using Microwave Kinetic Inductance Detectors James A. Schlaerth¹, N. G. Czakon², P. K. Day³, T. P. Downes², R. Duan², J. Glenn¹, S. R. Golwala², M. I. Hollister², H. G. LeDuc³, P. R. Maloney¹, B. A. Mazin⁴, O. Noroozian², J. Sayers², S. Siegel², A. Vayonakis², J. Zmuidzinas²

¹CASA/Univ. of Colorado, ²California Institute of Technology, ³Jet Propulsion Laboratory, ⁴University of California, Santa Barbara.

10:30 AM - 10:50 AM

Room 401

Microwave Kinetic Inductance Detectors (MKIDs) are superconducting resonators useful for detecting light from the millimeter-wave to the X-ray. These detectors are easily multiplexed, as the resonances can be tuned to slightly different frequencies, allowing hundreds of detectors to be read out simultaneously using a single feedline. The Multicolor Submillimeter Inductance Camera, MUSIC, will use 2304 antenna-coupled MKIDs in multicolor operation, with bands centered at wavelengths of 0.85, 1.1, 1.3 and 2.0 mm, beginning in 2011. Here we present the results of our demonstration instrument, DemoCam, containing a single 3-color array with 72 detectors and optics similar to MUSIC. We present sensitivities achieved at the telescope, and compare to those expected based upon laboratory tests. We explore the factors that limit the sensitivity, in particular electronics noise, antenna efficiency, and excess loading. We discuss mitigation of these factors, and how we plan to improve sensitivity to the level of background-limited performance for the scientific operation of MUSIC. Finally, we note the expected mapping speed and contributions of MUSIC to astrophysics, and in particular to the study of submillimeter galaxies. This research has been funded by grants from the National Science Foundation, the Gordon and Betty Moore Foundation, and the NASA Graduate Student Researchers Program.

413.05D

High Contrast Studies of Nearby Stars with Project 1640

Neil Zimmerman¹, B. R. Oppenheimer², S. Hinkley³, D. Brenner², A. Sivaramakrishnan⁴, I. Parry⁵, J. Crepp³, S. Hunt⁵, L. Pueyo⁴, E. Rice², L. Roberts⁶, G. Vasisht⁶, L. Hillenbrand³, R. Dekaney³, C. Beichman⁷ ¹Columbia University, ²American Museum of Natural History, ³Caltech, ⁴STScl, ⁵Institute of Astronomy, United Kingdom, ⁶JPL, ⁷NExScl.

10:50 AM - 11:10 AM

Room 401

Project 1640 is a coronagraphic integral field spectrograph designed for exoplanet imaging with the Hale Telescope at Palomar Observatory. One of the unique features of this instrument is its ability to simultaneously record high precision relative astrometry and coarse near-infrared spectra of faint companion candidates. Our rapid confirmation of Alcor's M-dwarf companion--which showed up during our survey of nearby A stars--demonstrates the power of this combination. By acquiring relative astrometry of Alcor and the faint neighboring source (1" separation at a contrast of 6 magnitudes) at two epochs just 100 days apart, we were able to establish the common parallax and proper motion of the stars. The same data provided a low-resolution near-infrared spectrum spanning the J and H bands,

enabling us to classify the companion as an M3-M4 dwarf. In a separate experiment, we have used Project 1640 as an imaging spectrograph (without the coronagraph) with a non-redundant aperture mask to achieve spectrally-resolved interferometry of a binary star system.

413.06

Demonstration Of A Robust Composite Deformable Secondary Mirror With Low Surface Error

Stephen Ammons¹, B. Coughenour¹, M. Hart¹, R. Romeo², R. Martin²

¹University of Arizona, ²Composite Mirror Applications.

11:10 AM - 11:20 AM

Room 401

I discuss recent improvements in the development of carbon fiber reinforced polymer (CFRP) as a lightweight substrate for primary and deformable secondary mirrors on ground- and space-based telescopes. Weight reductions for ground-based primary mirrors can significantly affect cost: The weight and material cost of a large ground-based telescope go roughly as the primary mirror mass. CFRP composites provide several advantages as a substrate for thin-shell adaptive secondary mirrors as well, including high stiffness-to-weight ratio, low coefficient of thermal expansion (CTE), and robustness. We use an 8 cm prototype CFRP thin-shell deformable mirror to show that spatial CTE variation may be addressed with mounted actuators. I present measurements of surface quality at a range of temperatures characteristic of mountaintop observatories. The figure error of the Al-coated reflective surface under best actuator correction is 43 nm RMS, placing it into consideration for use in near-IR astronomy. The low surface error internal to the outer ring of actuators (17 nm RMS at 15 C and 33 nm RMS at -5 C) suggests that larger mirrors will have a similar figure quality under actuator correction on ground-based Adaptive Optics systems. Surface roughness is low (< 3 nm P-V) at a variety of temperatures. These experiments demonstrate CFRP's potential as a lightweight, robust substrate for thin-shell deformable secondary mirrors.

413.07

The GMT-CFA-CARNEGIE-CATOLICA LARGE EARTH FINDER (G-CLEF): A Fiber-fed, Optical Echelle Spectrograph For The Giant Magellan Telescope

Andrew Szentgyorgyi¹, G. Furesz¹, A. Frebel¹, J. Geary¹, I. Evans¹, T. Norton¹, E. Hertz¹, J. DePonte Evans¹, A. Jordan², D. Guzman², H. Epps³, S. Barnes⁴, J. Crane⁵

¹Harvard-Smithsonian Center for Astrophysics, ²Pontificia Universidad Catolica de Chile, Chile, ³Lick Observatory, ⁴University of Canterbury, New Zealand, ⁵Carnegie Observatories.

11:20 AM - 11:30 AM

Room 401

The GMT-CfA-Carnegie-Catolica Large Earth Finder (G-CLEF) is a fiber-fed optical echelle spectrograph in concept design study phase for first light at the Giant Magellan Telescope. G-CLEF is designed to be a multipurpose echelle spectrograph that operates in a number of modes so as to enable precision radial velocity (RV) measurements, detailed abundance studies, isotopic abundance measurements and probe the IGM and ISM at high Z. Four resolution modes are implemented with image and pupil slicing. Extremely precise RV will be achieved by vacuum enclosing the spectrograph, with advanced fiber scrambling and state-of-the-art calibrators, especially ultra stabilized etalons and possibly laser frequency combs. The optical design is a asymmetric white pupil design with two camera arms splitting the 350 nm - 950 nm passband into red and blue channels. G-CLEF will have an extremely large, mosaiced echelle grating and volume phase holograph cross dispersers.

Thursday, January 13, 2011, 11:40 AM - 12:30 PM 414 *Addressing Unconscious Bias: Steps toward an Inclusive Scientific Culture* Invited Session *Ballroom 6AB*

414.01

Addressing Unconscious Bias: Steps toward an Inclusive Scientific Culture Abigail Stewart $^{1}\,$

¹University of Michigan.

Ballroom 6AB

In this talk I will outline the nature of unconscious bias, as it operates to exclude or marginalize some participants in the scientific community. I will show how bias results from non-conscious expectations about certain groups of people, including scientists and astronomers. I will outline scientific research in psychology, sociology and economics that has identified the impact these expectations have on interpersonal judgments that are at the heart of assessment of individuals' qualifications. This research helps us understand not only how bias operates within a single instance of evaluation, but how evaluation bias can accumulate over a career if not checked, creating an appearance of confirmation of biased expectations.

Some research has focused on how best to interrupt and mitigate unconscious bias, and many institutions--including the University of Michigan--have identified strategic interventions at key points of institutional decision-making (particularly hiring, annual review, and promotion) that can make a difference. The NSF ADVANCE Institutional Transformation program encouraged institutions to draw on the social science literature to create experimental approaches to addressing unconscious bias. I will outline four approaches to intervention that have arisen through the ADVANCE program: (1) systematic education that increases awareness among decisionmakers of how evaluation bias operates; (2) development of practices that mitigate the operation of bias even when it is out of conscious awareness; (3) creation of institutional policies that routinize and sanction these practices; and (4) holding leaders accountable for these implementation of these new practices and policies. Although I will focus on ways to address unconscious bias within scientific institutions (colleges and universities, laboratories and research centers, etc.), I will close by considering how scientific organizations can address unconscious bias and contribute to creating an inclusive scientific culture.

Thursday, January 13, 2011, 2:00 PM - 3:30 PM 415 *Exoplanet Systems - Characterization and Dynamics* Oral Session *Ballroom 6A*

415.01

Origin, Dynamics and Stability of the Mutually Inclined Orbits of the u Andromedae Planetary System Rory Barnes¹, R. Greenberg², T. R. Quinn¹, B. McArthur³, A. Antonsen¹, G. F. Benedict³ ¹University of Washington, ²University of Arizona, ³University of Texas. 2:00 PM - 2:10 PM *Ballroom 6A* The planetary system of u Andromedae is the first to display evidence for mutually inclined orbits around a main sequence star (McArthur et al. 2010). Moreover, the planets u And c and d have orbital elements that oscillate with large amplitudes and lie very close to the limits of stability. The substantial

mutual inclination, as well as its other orbital characteristics, may offer insight into the dynamical history

of this system, and thus into planetary formation processes in general. The u And system may be influenced by a nearby low-mass star, u And B, which could perturb the planetary orbits, but the effect is too weak to modify two coplanar orbits into the observed mutual inclination of ~30 degrees. However, it could have perturbed the original planetary system enough to incite encounters or collisions among the planets that subsequently raised the mutual inclinations of the remaining planets to the current values. Our simulations do produce systems similar to that of u And, although even with the high inclinations they tend to be further from the stability boundary than suggested by the current best orbits for the observed system. Thus, scattering is a plausible mechanism to explain the observed inclinations of u And c and d. While, perturbations from u And B may have incited the scattering, it may also have been caused by instabilities among the planets themselves. We also examine a wide range of masses and orbits for planet b, which has not been detected astrometrically, in order to constrain the parameter space that can support a stable three-planet system.

415.02D

Discovering Transiting Planets from the Ground, Characterizing them from Space Philip Nutzman¹

¹UC Santa Cruz. 2:10 PM - 2:30 PM Ballroom 6A

I reflect on the prospects for detecting Earth-like, habitable planets from the ground by targeting nearby M dwarf stars. I present two design studies for ground-based transit surveys seeking habitable, Earth-like planets. The MEarth Observatory, which recently discovered the 6.5 Earth mass GJ 1214b, was largely shaped by the conclusions of the first design study and may evolve according to recommendations from the second.

I also discuss the use of space-based observatories to characterize transiting exoplanets. I present a Spitzer 8 micron study of the intriguingly dense planet HD 149026b. I also present Hubble FGS observations of the e=0.67 exoplanet HD 17156b. These observations were part of a major Hubble program to detect oscillation modes in the star HD 17156. By combining constraints from asteroseismology and transit photometry, I improve the determination of planetary properties by an order of magnitude versus previous studies.

415.03

Dynamical Stability of Earth-mass Planets in the Presence of Two Giant Planets Ravi Kumar Kopparapu¹, R. Barnes²

¹*Pennsylvania State University,* ²*University of Washington.*

2:30 PM - 2:40 PM

Ballroom 6A

We study the dynamical stability of an Earth mass planet in the presence of two giant planets in the context of Hill & amp; Lagrange stability boundaries. Previous studies have shown that, for a two planet system, these boundaries are almost identical. Here, we explore if Hill stability can be extrapolated to determine if a system of two giant planets can support an Earth-mass planet in between, focusing on systems which have stable habitable zones. We compute the proximity to the Hill stability boundary for a large number of hypothetical systems of two giant planets with mutual inclinations of 0,5,10, 30 degrees and an eccentricity range of 0-0.6. We then place a hypothetical terrestrial mass planet in between the two planets, and perform N-body simulations to determine Lagrange stability, meaning no escape or exchanges. Unlike the two-planet case, we find that stability boundaries do not trace the analytic Hill limit. We therefore derive an empirical boundary which may be used in lieu of expensive N-

nody calculations. These results may ease the search for habitable planets, as well as illuminate the possibility that most planetary systems are packed.

415.04

Fundamental Astrophysical Parameters For The Late-type Exoplanet Host Stars Gj 581, Gj 614, And Gj 649

Kaspar von Braun¹, T. S. Boyajian², G. T. van Belle³, D. R. Ciardi¹, M. Lopez-Morales⁴, H. A. McAlister², T. Henry², S. R. Kane¹, C. Farrington⁵, P. J. Goldfinger⁵, G. Schaefer⁵, T. A. ten Brummelaar⁵, S. Ridgway⁶, L. Sturmann⁵, J. Sturmann⁵, N. H. Turner⁵

¹Caltech, ²Georgia State University, ³ESO, Germany, ⁴DTM / Carnegie Institution, ⁵The CHARA Array, ⁶NOAO.

2:40 PM - 2:50 PM

Ballroom 6A

The precision in the determination of the fundamental astrophysical parameters of extrasolar planets is, at best, as good as the precision in the characterization of their respective host stars, except in the currently rare cases in which the planets are directly imaged. Furthermore, the formation, evolution, and radiation environment of extrasolar planets are sensitively dependent on the astrophysical properties of the parent stars, including location and size of the habitable zone. The determination of these stellar astrophysical parameters is therefore critical to insights into exoplanet characterization. We use interferometric measurements obtained with the CHARA Array coupled with Hipparcos parallaxes to directly determine linear radii of the late-type exoplanet hosting stars GJ 581, GJ 614 (14 Her), and GJ 649. We additionally calculate their effective temperatures by means of spectral energy distribution fitting. Finally, we use literature log g values, combined with our directly determined radii, to constrain stellar masses. Of these targets, GJ 581 is of particular interest since it hosts four planets of which two are super earths and another one is in the habitable zone. In our presentation, we show the values of the stellar parameters and compare them to literature values calculated in a different manner.

415.05

Lyapunov Exponent Criterion for Stability of Planetary Orbits in Binary Systems

Zdzislaw E. Musielak¹, B. Quarles¹, J. Eberle¹, M. Cuntz¹

¹Univ. of Texas, Arlington.

2:50 PM - 3:00 PM Ballroom 6A

The existence of planets in stellar binary systems is now well-confirmed by many observations. Stability of planetary orbits in these systems has extensively been studied and some attempts have been made to establish stringent stability criteria for the orbits. In this paper, we contribute to the ongoing work on the stability criteria in binary systems by introducing a Lyapunov exponent criterion. We have computed the Lyapunov exponents, the Lyapunov dimension and the time series spectra for planets in binary system. The obtained results demonstrate when a system becomes unstable by orbital energy criterion and the method of Lyapunov exponents provides a quantitative classification scale to characterize the instability. By applying the maximum Lyapunov exponent to the parameter space, which covers mass and distance ratios for the considered binary systems, we determined regions of stability and used the time series spectra and the Lyapunov dimension to illustrate the reasons behind the stability. Specific applications of the criterion to binary systems with known planets will also be discussed.

415.06

The Occurrence And Mass Distribution Of Close-in Super-earths, Neptunes, And Jupiters Andrew Howard¹, G. Marcy¹, J. A. Johnson², D. Fischer³, J. Wright⁴, J. Valenti⁵, J. Anderson⁵, D. N. C. Lin⁶, S. Ida⁷ ¹UC Berkeley, ²Caltech, ³Yale University, ⁴Penn State University, ⁵STScl, ⁶UC Santa Cruz, ⁷Toyko Institute of Technology, Japan. 3:00 PM - 3:10 PM

Ballroom 6A

We report the occurrence rate of close-in planets (orbital periods less than 50 days) based on precise Doppler measurements of 166 G and K-type dwarf stars. We statistically study the planet detections and non-detections on a star-by-star basis using 3.5 years of Keck RV measurements made specifically for the NASA-UC Eta-Earth Survey. We measure increasing planet occurrence with decreasing planet mass over three decades in planet mass, from Jupiters to super-Earths. Extrapolation of a power law mass distribution fitted to our measurements, df/dlogM = $0.39M^{-0.48}$, predicts that 23% of stars harbor a closein, Earth-like planet (0.5-2.0 Earth-masses). Population synthesis models of planet formation by core accretion predict a deficit of planets in the domain of 5-30 Earth-masses (the "planet desert") and orbital periods less than 50 days. This region of parameter space is in fact well populated, implying that such models need significant revision.

415.07

The Origin of Retrograde Hot Jupiters

Smadar Naoz¹, W. Farr¹, Y. Lithwick¹, F. Rasio¹

¹Northwestern University.

3:10 PM - 3:20 PM

Ballroom 6A

The search for extra-solar planets has led to the surprising discovery of many Jupiter-like planets in very close proximity to their host star (the so called hot Jupiters). Many have been observed to be on orbits inclined with respect to the equator of the star, some even in retrograde orbits. This poses a unique challenge to many planet formation scenarios. Here we show that the presence of an additional, moderately inclined and eccentric massive planet companion in a planetary system can naturally explain close, inclined and eccentric orbits. The flow of angular momentum from the hot Jupiter's orbit to the orbit of the perturber can lead to both high eccentricities and inclinations, and even completely flip the hot Jupiter's orbit. For the first time we provide a complete treatment of the octupole-order secular dynamics, while also including tidal friction. In this treatment a brief excursion to very high eccentricity during the chaotic evolution of the hot Jupiter's orbit can lead to rapid tidal capture; in some instances the orientation can flip before the capture.

415.08

Super-Earths and Life

Lisa Kaltenegger¹

¹*MPIA/Harvard University, CfA, Germany.* 3:20 PM - 3:30 PM

Ballroom 6A

Super-Earth & Life: a fascinating puzzle

The first Super-Earths have recently been discovered. This number will raise significantly when Kepler planetary candidates will be confirmed. We show models for rocky Super-Earth atmospheres and derive detectable spectroscopic features that can indicate habitable environments in transmission and emergent spectra for future space- and ground based telescopes like the James Webb Space Telescope. What does it take for super-Earths to support life?

As a specific example, we show under which condition the recently discovered M-dwarf planets around GI581 are potentially habitable. This talk will focus on the cross-disciplinary connection between planetary science, biology and astronomy and explore its remotely detectable features in a planets

atmosphere. The observational features of the planet are used to derive observable quantities to examine if our concept of habitability is correct and how we can find the first habitable new worlds in the sky.

416

The Formation of Very Massive Stars Oral Session Ballroom 6B

416.01 The Dynamical State Of Massive Cores

Di Li¹, J. Kauffmann¹, Q. Zhang² ¹Jet Propulsion Laboratory, ²Harvard Smithsonian Center for Astrophysics. 2:00 PM - 2:10 PM Ballroom 6B

A comprehensive data set of massive quiescent cores in Orion have been assembled to study early phases of massive star formation. These cores were mapped in spectral tracers, such as NH_3 (VLA, GBT, and Effellsberg), N_2H^+ (CARMA and FCRAO), HCO^+ (CARMA and CSO) as well as dust continuum by Spitzer and CSO. Part of the data set were published in Li et al. 2003, Li et al. 2007, and Velusamy et al. 2008. These massive cores were found to be largely externally heated, roughly 10 times more massive than cores

in low mass star-forming regions, and have a core mass function significantly flatter than the Salpeter initial mass function (IMF). In this talk, I will focus on results based on the combined VLA and GBT NH_3 maps. At a beam size of about 4", we resolve a set of massive cores down to 0.01 pc. Based on direct measurement of temperature and turbulence, these cores do not have adequate pressure support and are probably supercritical. They are sites of ongoing and likely future star formation.

416.02D

The Formation of the Most Massive Stars in the Galaxy Roberto Galvan-Madrid¹

¹*Harvard-Smithsonian Center for Astrophysics.*

2:10 PM - 2:30 PM

Ballroom 6B

The 'really' massive stars (those with more than 15 to 20 solar masses) likely start to ionize their surroundings before they reach their final mass. How can they accrete in spite of the presence of over-pressurized gas? We present results of Submillimeter Array (SMA) and Very Large Array (VLA) studies of massive-star formation regions in the early stages of ionization: Molecular-line observations at resolutions from a few arcsec to 0.3 arcsec reveal the presence of rotation, infall, and/or outflow from parsec scales to <0.05 pc. Small groups of massive (proto)stars are found at different evolutionary stages. The hypercompact HII regions with positive cm-to-mm spectral indices tend to be the smallest and most embedded, and they appear to have density gradients and/or clumpiness within the ionized gas. In the innermost few thousand AU, the ionized gas is sometimes found to have organized motions, probably in the form of outflow and/or rotation. Multiepoch observations of the free-free continuum reveal significant flux variations in timescales of years, attributable to interactions with the surrounding molecular gas. These observations, as well as recent models and numerical simulations of HII region evolution in star-forming accretion flows, favor a picture in which: i) Stars with M > 15 Msun form by accretion processes similar to those of lower-mass stars, but with significant ionization. ii) The masses of the cores from which these stars form are set until relatively late times in the evolution of the cluster. iii)

Accretion can continue past the onset of an HII region. iv) The HII region is kept partially confined by its own molecular accretion flow for a period of time.

416.03D

Massive Star Formation: The Role of Disks

Cassandra L. Fallscheer¹, H. Beuther², J. Sauter³, S. Wolf³, Q. Zhang⁴, E. Keto⁴, T. K. Sridharan⁴ ¹NRC/HIA, Canada, ²MPIA, Germany, ³University of Kiel, Germany, ⁴CfA. 2:30 PM - 2:50 PM

Ballroom 6B

We have obtained multiple data sets from the SMA, PdBI, and IRAM 30m telescope of the Infrared Dark Cloud IRDC18223-3, the High-Mass Protostellar Object IRAS18151-1208, and the hot core source IRAS18507+0121 in order to search for clues regarding the role of rotation and disks in high mass star formation. These three objects allow us to compare the central-most regions surrounding the embedded continuum source at three different evolutionary stages of the formation process. Toward all three regions we see rotational or elongated structures perpendicular to the molecular outflows. Similarities and differences in the evolutionary sequence are discussed in the context of core and disk evolution. We have also carried out continuum and line radiative transfer modeling of the disk-like structures. Having a more complete picture of the evolutionary process that a massive star experiences will contribute significantly to the future of massive star formation research. Support for this project comes from the Deutsche Forschungsgemeinschaft and the International Max-Planck Research School for Astronomy and Cosmic Physics at the University of Heidelberg.

416.04

Collisional Formation of Very Massive Stars in Young Dense Clusters Nickolas $\mathsf{Moeckel}^1$

¹University of Cambridge, United Kingdom.

2:50 PM - 3:00 PM

Ballroom 6B

Numerical studies of the early evolution of star clusters have traditionally been based on full hydrodynamic treatments or a purely gravitational N-body approach . I will

discuss recent work that pushes the N-body techniques toward a more realistic gas treatment. In particular I will focus on the behavior of very young clusters as they accrete gas, leading to compact configurations that are robust to gas expulsion, and in extreme cases to the collisional growth of very massive stars.

417 *Spiral Galaxies* Oral Session *Ballroom 6C*

417.01

Disk Truncations and Stellar Migrations in the GHOSTS Survey

David J. Radburn-Smith¹, R. Roskar², V. Debattista³, R. de Jong⁴, GHOSTS Collaboration ¹University of Washington, ²University of Zurich, Switzerland, ³University of Central Lancashire, United Kingdom, ⁴AIP, Germany. 2:00 PM - 2:10 PM

Ballroom 6C

The GHOSTS survey is the largest study of the resolved stellar populations in the outskirts of disk galaxies to date. Using the GHOSTS sample of 14 nearby galaxies, this presentation will explore the

phenomenon of disk truncations and show how the data support the idea of substantial stellar migration in the galaxy disk and beyond. Such migrations may have important ramifications for the study of disk-galaxy evolution. Future directions for this work, and the GHOSTS survey as a whole, will also be discussed.

417.02D

Analysis Of The Spatial Distribution Of Stars, Gas And Dust In Nearby Galaxies Juan Carlos Munoz-Mateos¹, A. Gil de Paz², J. Zamorano²

¹National Radio Astronomy Observatory, ²Universidad Complutense de Madrid, Spain.

2:10 PM - 2:30 PM

Ballroom 6C

I will discuss how the physical properties of dust in nearby galaxies change as we move away from each galaxy's center. Using multi-wavelength data from the Spitzer Infrared Nearby Galaxies survey, we have derived the radial variation of several properties of dust, such as the internal extinction, the dust mass surface density, the abundance of Polycyclic Aromatic Hydrocarbons and the dust-to-gas ratio, among others. These results are part of a larger study, in which the present-day distribution of stars of different ages, gas and dust in nearby galaxies is used as fossil tracer of their past evolution.

417.03

Stellar Population Models of the Outer Disks of Spiral Galaxies Using Representative Star Formation Histories: Implications for UV, Optical and NIR Colors

Kate L. Barnes¹, L. van Zee¹, J. D. Dowell²

¹Indiana University Bloomington, ²University of New Mexico.

2:30 PM - 2:40 PM

Ballroom 6C

We generate star formation histories representative of the low present and past star formation rates in the outer disks of spiral galaxies. The model star formation histories consist of episodic sampling of exponentially declining star formation rates. We study the effects of these star formation histories on UV, optical and NIR colors using stellar population models from Bruzual and Charlot (2003). We find significant dispersion in the UV colors, and negligible dispersion in both the optical and NIR colors. We compare our Monte Carlo simulations to recent observations of the outer disks of nearby spiral galaxies. Our results indicate that the large dispersion in UV colors in outer disks may be a result of low star formation frequency.

417.04

Constraining Spatially Resolved Kennicutt-Schmidt Law

Nurur Rahman¹, A. Bolatto¹, STING collaboration

¹University of Maryland.

2:40 PM - 2:50 PM

Ballroom 6C

What is the power law index in the spatially resolved molecular Kennicutt-Schmidt relation? Whether the relation between molecular gas and star formation is linear or not has important implications on the physics regulating star formation activity on galactic scales. Observational studies, however, frequently arrive at inconsistent results even on the same object, mostly because of methodological differences. We discuss a systematic study carried out on two nearby galactic disks (M99 and M74), which assesses the effects of the choice of SFR tracer, the removal of diffuse emission, and the sampling and fitting methodologies. We find that while the result for the power law index in the faint emission is very sensitive to the methodology, the result of the measurement is well defined in the bright regions of

galaxies. There we obtain an approximately linear relation independent of the choice of SFR tracer if the fraction of diffuse emission is smaller than 30-40%.

417.05

Detection of a Hot Gaseous Halo Around the Spiral Galaxy NGC 1961

Michael Anderson¹, J. N. Bregman¹

¹Univ. Of Michigan. 2:50 PM - 3:00 PM

Ballroom 6C

Hot gaseous haloes are predicted around all large galaxies as an effect of galaxy formation, forming a source of material for accretion. However, such hot haloes have never been detected at distances beyond a few kpc around a spiral galaxy. We used the Chandra ACIS-I instrument to look for diffuse X-ray emission around an ideal candidate galaxy: the isolated giant spiral NGC 1961. We observed four quadrants around the galaxy for 30 ks each, carefully subtracted background emission and point source emission, and found diffuse emission that appears to extend to at least 50 kpc. We fit β -models to the emission, and estimate a total hot halo mass of 5.3-6.0×10¹⁰ M_☉ out to 500 kpc. This is a large reservoir of hot gas, but falls significantly below observational upper limits set by pervious searches, and suggests that NGC 1961 is missing 85% of its baryons relative to the cosmic mean -- a surprising defecit for such a massive structure.

417.06

Stochastic Spiral Arms in Disk Galaxies

Elena D'Onghia¹, M. Vogelsberger¹, L. Hernquist¹

¹Center for Astrophysics. 3:00 PM - 3:10 PM Ballroom 6C

We employ a set of high-resolution simulations of disk galaxies to argue that dark matter substructures passing through the disk hardly produce transient features in disk, like multi-armed spiral patterns. Indeed, our studies indicate that stochastic spiral arms in galaxies have different origin.

417.07

Super-Exponential Growth of Large Scale Magnetic Fields in Rotating Systems

Ethan T. Vishniac¹, D. Shapovalov²

¹*McMaster University, Canada,* ²*Johns Hopkins University.*

3:10 PM - 3:20 PM

Ballroom 6C

We consider the growth of large scale magnetic fields in a periodic box with an imposed shear as a simplified model for the growth of galactic magnetic fields. The simulations show very rapid growth of large scale magnetic fields, driven by the divergence of the induced magnetic helicity flux. We show that this flux is independent of the existence of a large scale field, and that the galactic dynamo will grow to saturation in one kinematic e=folding time. We also show that, in general, there is no purely kinematic regime for alpha-Omega dynamos.

417.08

Dust and Stellar Emission of Nearby Galaxies in the KINGFISH Herschel Survey

Ramin A. Skibba¹, C. W. Engelbracht¹, L. Hunt², D. Dale³, B. Johnson⁴, B. Groves⁵, J. Hinz¹, E. Murphy⁶, S. Zibetti⁷, KINGFISH Team

¹University of Arizona, ²INAF - Astrophysical Observatory of Arcetri, Italy, ³University of Wyoming,

⁴University of Cambridge, United Kingdom, ⁵Leiden University, Netherlands, ⁶Spitzer Science Center, ⁷Max Planck Institute for Astronomy, Germany.

3:20 PM - 3:30 PM

Ballroom 6C

We exploit data from the ultraviolet to submillimeter wavelengths of the 61 nearby galaxies in KINGFISH. We use the spectral energy distributions computed by Dale et al., using data from GALEX, SDSS (or other optical), 2MASS, Spitzer, and SCUBA, and to these we add SPIRE data from Herschel. Herschel observations allow us to trace cold dust components invisible to Spitzer, with reduced systematic uncertainties relative to ground-based submillimeter measurements. By using these data together, we can now measure precisely how much stellar radiation is intercepted and re-radiated by dust, and how this quantity varies with galaxy properties. We also determine what kind of local galaxies are most similar to those dominating the extragalactic background light.

We find that the dust/stellar flux ratio varies with morphology, metallicity, and total infrared luminosity in a way that suggests a common evolutionary sequence for some galaxies. We also obtain a correlation between the dust/stellar flux ratio and dust/stellar mass, although there is substantial scatter for latetype galaxies. Early-types and early-type spirals have a significant correlation between the dust/stellar ratio and specific star formation rate and dust temperature, suggesting that the bright far-IR emission of some galaxies is due to star formation, which is heating some of the dust populations. For S0 and Sa galaxies, relatively little ongoing star formation can significantly heat the dust. Finally, we discuss implications of our results for galaxy formation models and high redshift studies.

Based on observations obtained with the Herschel Space Telescope as part of KINGFISH (Key Insights on Nearby Galaxies: a Far Infrared Survey with Herschel; P.I.: R.C. Kennicutt), one of the Herschel Open Time Key Projects.

418 *Exoplanet Atmospheres - Observations and Modeling II* Oral Session *Room 611/612*

418.01

Atmospheric Constraints of Two Exoplanets Using The Spitzer Space Telescope

Kevin Stevenson¹, J. Harrington¹, J. Fortney², N. Madhusudhan³, S. Seager³, D. Deming⁴, S. Nymeyer¹, R. A. Hardy¹, W. C. Bowman¹

¹University of Central Florida, ²UC Santa Cruz, ³Massachusetts Institute of Technology, ⁴NASA's Goddard Space Flight Center.

2:00 PM - 2:10 PM

Room 611/612

The Spitzer Exoplanet Target of Opportunity program observes secondary eclipses, when the planet passes behind its parent star, to provide direct measurements of emitted planetary flux, thus constraining atmospheric models. Here we present dayside atmospheric constraints of two exoplanets using a total of 16 secondary eclipse observations at six different infrared wavelengths. The first exoplanet is HD 149026b which transits its large, relatively hot G0 parent star at a distance of only 0.042 AU. The Saturn-sized planet's high average density suggests that most of its mass must be in its large, ~80 Earth-mass icy/rocky core. The second planet, GJ 436b, is a hot Neptune that orbits a small, Mdwarf star and is currently Earth's nearest transiting exoplanet at a distance of only 33 ly. We also present a new technique that models Spitzer's position-dependent sensitivity effect using a high resolution, bilinearly-interpolated subpixel sensitivity map. Spitzer is operated by the Jet Propulsion
Laboratory, California Institute of Technology under a contract with NASA, which provided support for this work.

418.02

The Orbit and Atmosphere of Exoplanet WASP-12b Revealed by Spitzer Secondary Eclipses

Joseph Harrington¹, N. Madhusudhan², R. A. Hardy¹, C. J. Campo¹, K. B. Stevenson¹, S. Nymeyer¹, D. Ragozzine³, N. B. Lust¹, D. R. Anderson⁴, A. Collier-Cameron⁵, J. Blecic¹, C. B. T. Britt¹, W. C. Bowman¹, P. J. Wheatley⁶, T. J. Loredo⁷, D. Deming⁸, L. Hebb⁹, C. Hellier⁴, P. F. L. Maxted⁴, D. Pollaco¹⁰, R. G. West¹¹ ¹University of Central Florida, ²Massachusetts Institute of Technology, ³Harvard-Smithsonian Center for Astrophysics, ⁴Keele University, United Kingdom, ⁵University of St. Andrews, United Kingdom, ⁶University of Warwick, United Kingdom, ¹¹University, ⁸NASA's GSFC, ⁹Vanderbilt University, ¹⁰Queen's University, United Kingdom, ¹¹University of Leicester, United Kingdom.

2:10 PM - 2:20 PM

Room 611/612

Exoplanet WASP-12b has a period of 1.09 days and is close enough to its G0 star that, if eccentric, its orbital precession period of a few decades could be measureable in just a few years with high-precsion secondary eclipse measurements. We observed four secondary eclipses of WASP-12b with the Spitzer Space Telescope separated by several years. Combined with ground-based transit and radial-velocity measurements, we find a small eccentricity but no measurable precession. However, the eclipse depths have S/N as high as 29, among the highest ever obtained. The brightness temperatures are ~3000 K, allowing atmospheric characterization at a nearly unprecedented level, especially when combined with the ground-based, near-infrared eclipses of Croll et al. Our analysis used a Markov-Chain Monte Carlo method to explore the space of thermal profiles and molecular abundances of CO, CH₄, H₂O, CO₂, and included also collision-induced absorption and TiO/VO. It calculated over 4 million spectra and integrated them over the seven secondary eclipse bandpasses to compare to the observations. We will present the results at the meeting.

418.03

A Subaru/MMT Study of the Atmospheres of the Planets Orbiting HR 8799

Thayne M. Currie¹, A. Burrows², Y. Itoh³, M. Fukagawa⁴, D. Fabrycky⁵, R. Murray-Clay⁶, N. Madhusudhan², K. Hamaguchi¹

¹NASA-Goddard Space Flight Center, ²Princeton University, ³Kobe University, Japan, ⁴Nagoya University, Japan, ⁵UC-Santa Cruz, ⁶Harvard-Smithsonian Center for Astrophysics.

2:20 PM - 2:30 PM

Room 611/612

We present new Subaru data and a rereduction of archival MMT data for the HR 8799 planetary system from 1 to 5 microns. We compare photometry from these data to that for field L/T dwarfs and synthetic SEDs for substellar objects with wide range of temperatures, gravities, and cloud prescriptions. Our analysis strongly suggests that HR 8799bcd have atmospheres dissimilar from almost any brown dwarf over a wide wavelength range. Best-fit models yield temperatures of 900-1100K and masses between 7 and 9 Mjupiter, roughly consistent with values derived from cooling models, and suggest that extensive cloud coverage is a likely source of the SED differences between these planets and brown dwarfs with similar temperatures.

418.04

Near-ir Spectra Of The Planets HR8799b And HR8799c Bruce Macintosh¹, T. Barman², Q. M. Konopacky¹, C. Marois³ ¹*LLNL*, ²*Lowell Observatory*, ³*HIA*, *Canada*. 2:30 PM - 2:40 PM

Room 611/612

The directly-imaged HR8799 system represents a unique window into exoplanet formation and evolution with three massive coeval planets accesible to characterization using adaptive optics on modern telescopes. One such window is spectroscopic characterization. We have used the OSIRIS near-IR integral field spectrograph on the W.M. Keck telescope to study the two outermost planets. Taking advantage of the 3-dimensional OSIRIS data product we can separate artifact speckles noise from the true planetary signal. H and K band spectra of these two planets, among the coldest planetary bodies ever characterized, significantly diverge from observed brown dwarfs and older models of planetary atmospheres, with evidence for thick clouds and an absence of strong methane absorption in spite of their low (<1100K) effective temperatures.

Portions of this work prepared by LLNL under Contract DE-AC52-07NA27344 and under support from the NASA Origins program.

418.05

Atmospheric Properties Of The Young Exoplanets Hr 8799 b And c

Travis S. Barman¹, B. Macintosh², Q. Konopacky², C. Marois³

¹Lowell Observatory, ²LLNL, ³Herzberg Institute of Astrophysics, Canada.

2:40 PM - 2:50 PM

Room 611/612

The HR 8799 planetary system provides a unique opportunity to study the atmospheric properties of three young, coeval, planets at the extreme high-mass range of planet formation. We will compare broad-band near-IR spectra of the two outermost planets, c and b, to model atmospheres. In addition to their bulk properties (effective temperature, surface gravity, and size), the level of cloud coverage and departure from a chemical equilibrium CO/CH4 ratio will be discussed. Our effective temperature estimates also disagree, by several hundred Kelvin, with standard interior cooling-track predictions for the estimated age and measured luminosities of these planets. Possible sources of this disagreement will be presented.

418.06

A Ground-based Transmission Spectrum Of The Super-earth Planet Gj1214b

Jacob Bean¹, E. Kempton², D. Homeier³

¹Harvard-Smithsonian Center for Astrophysics, ²UC Santa Cruz, ³Institute for Astrophysics Goettingen, Germany.

2:50 PM - 3:00 PM

Room 611/612

We have recently obtained a transmission spectrum of the super-earth planet GJ1214b. These measurements were made from the ground in the red part of the optical using a new technique for eclipse spectroscopy that yields space-telescope quality data. The measurements provide important constraints on GJ1214b's atmospheric composition, but don't necessarily yield a completely definitive result as to its overall nature. I will discuss our measurements, their implications, and also future observations that could provide more insight to this interesting world.

418.07

Modeling The Atmosphere Of The Transiting Super-earth GJ 1214b

Eliza Kempton¹, J. Fortney¹, K. Zahnle² ¹U.C. Santa Cruz, ²NASA Ames. 3:00 PM - 3:10 PM

Room 611/612

GJ 1214b is the first transiting super-Earth that requires a significant atmosphere to explain its observed mass and radius. Two classes of models have been proposed to explain the planet's observed low density. One requires a rocky inner core with a significant hydrogen-helium atmosphere. The other is a "water world" scenario where the bulk of the planet would be composed primarily of water. Such a planet would be enshrouded by a thick water vapor atmosphere. Breaking the degeneracy between these two classes of models requires observing the planet's atmosphere to identify the key differences between a mostly hydrogen atmosphere and a water atmosphere. Our modeling effort reveals that transit (transmission) spectroscopy should be the most straightforward way of affirming the composition of GJ 1214b's atmosphere. Furthermore, the signature of a hydrogen-dominated atmosphere on GJ 1214b should be quite large -- on the order of 0.1-0.3% relative to its host star -- and readily observable with current ground-based and space-based instrumentation. The presence of clouds or hazes in the planet's atmosphere could further complicate the interpretation of transmission spectra for GJ 1214b. We find that some chemical species may condense to form clouds in the atmosphere of GJ 1214b. We have additionally applied a photochemical model to this planet, and we find that hydrocarbon hazes may readily form in GJ 1214b's atmosphere.

418.08

Using Precise Ground-based Photometry In The Near-infrared To Characterize Hot Jupiters' Thermal Emission And The Spectral Features Of Super-Earths

Bryce Croll¹, L. Albert², R. Jayawardhana¹, J. J. Fortney³, D. Lafreniere², E. Miller-Ricci Kempton³, M. Cushing⁴, J. A. Johnson⁵, A. Bonomo⁶, M. Deleuil⁶, C. Moutou⁶

¹University of Toronto, Canada, ²Universite de Montreal, Canada, ³University of California Santa Cruz, ⁴NASA Jet Propulsion Laboratory, ⁵California Institute of Technology, ⁶Laboratoire d'Astrophysique de Marseille, France.

3:10 PM - 3:30 PM

Room 611/612

I will present results from our ongoing program using the Wide-field Infrared Camera (WIRCam) on the Canada-France-Hawaii Telescope (CFHT) to detect thermal emission from hot Jupiters in the nearinfrared and our new program to search for spectral features in the transmission spectrum of the Super-Earth GJ 1214b . We've detected the thermal emission of several hot Jupiters in Ks-band (TrES-2b, TrES-3b, and WASP-3b) to date as well as the thermal emission of the highly irradiated exoplanet WASP-12b in the J, H and Ks-bands. These detections allow us to characterize these planets' spectral energy distributions near their blackbody peaks, and when combined with results from shorter and longer wavelengths, allow us to constrain the combination of the Bond albedo and day-to-night-side redistribution of heat in these planets atmospheres as well as their pressure-temperature profiles with depth. These detections allow us to answer other scientific questions such as whether hot Jupiters are stormy, and whether there is any evidence that the intriguing exoplanet WASP-12b is precessing or if there is material being tidally stripped from WASP-12b and forming a circumstellar disk. Lastly, I will present recent results from our program to look for spectral features in the transmission spectrum of the recently discovered Super-Earth GJ 1214b by searching for variations in its transit depth from nearsimultaneous photometry in two near-infrared filters; if these spectral features were detected it would argue that GJ 1214b has an atmosphere predominantly composed of hydrogen and helium and that it has a rocky core. If that is the case, GJ 1214b, the first Super-Earth we can readily characterize, would arguably be better described as a sub-Neptune.

419 *Circumstellar Disks III* Oral Session *Room 618/620*

419.01D

The Fate Of Planetary Systems Beyond The Main Sequence. Amy Bonsor $^1\!,$ M. C. $Wyatt^1$

¹University of Cambridge, United Kingdom.

2:00 PM - 2:20 PM

Room 618/620

Discs of dust and rocks, analogous to the Solar System's asteroid or Kuiper belt are observed around hundreds of main sequence stars. There are over 400 detections of exoplanets to date around main sequence stars. Very little, however, is known about the fate of planetary systems when the star evolves off the main sequence. Do they survive the star's evolution? Should we be able to detect planetary systems around evolved stars? Hot, dusty discs are observed around a handful of white dwarfs. Can we link these observations with main sequence planetary systems?

I present semi-analytic models that evolve the population of debris discs observed around main sequence A stars through to the white dwarf phase, discussing the effects of stellar evolution on them and their detectability post-main sequence. I also discuss the dynamical implications of stellar mass loss on a planetary systems, with particular reference to the formation of the observed hot dusty discs around white dwarfs.

419.02D

Diagnosing the State of Planet Formation through Debris Disk Modeling Laura Churcher¹, M. Wyatt¹

¹University of Cambridge, United Kingdom.

2:20 PM - 2:40 PM

Room 618/620

Circumstellar dust exists in debris disks around hundreds of main sequence stars. This dust must be continually replenished through collisions between larger planetesimals, analogous to the bodies in the Solar System's Asteroid and Kuiper belts.

I present resolved mid-infrared imaging of debris disks around three young main sequence stars: Eta Tel, HD191089 and HR4796. I also show Herschel PACS far-IR imaging of the newly resolved debris disk around Beta Leo. I have modeled these disks to constrain the state of planet formation in these systems. These diverse disks show inner holes, asymmetries from perturbing planets and evidence of self-stirring from ongoing planet formation.

419.03

Probing the Origins of Solar Systems with Millimeter-wave Interferometry

Andrea Isella¹, L. Perez¹, J. M. Carpenter¹

¹CALTECH.

2:40 PM - 2:50 PM

Room 618/620

It is generally accepted that circumstellar disks around pre-main sequence stars are the birth-places of planets. Nevertheless, it is still very uncertain how, when and where planet formation occurs within the disks. I will discuss how we can use millimeter-wave interferometry to address these questions, focusing, in particular, on the derivation of the radial distribution of the circumstellar material and of the dust properties. I will present the most recent results achieved with the Combined Array for Research in

Millimeter-wave Astronomy (CARMA) and discuss what we will be able to achieve with ALMA in the next future.

419.04

Studying Grain Growth using Resolved Images of Protoplanetary Disks with CARMA Laura M. Perez¹, A. Isella¹, J. M. Carpenter¹

¹California Institute of Technology.

2:50 PM - 3:00 PM

Room 618/620

Circumstellar disks around pre-main sequence stars are believed to be the birthplace of planets. High resolution imaging at millimeter wavelengths provides an important tool to identify the density and temperature distribution of material in the mid-plane of the disks where planets may form. The Combined Array for Research in Millimeter-wave Astronomy (CARMA) provides a unique opportunity to spatially resolve circumstellar disks in the nearby Taurus and Ophiuchus star-forming regions at spatial scales of 20 - 40 AU. Multi-wavelength millimeter observations can be used to measure radial variations in the spectral slope of the dust opacity. Any changes in the slope with radius will indicate variations & hosp; in the dust properties (e.g. composition, grain size distribution) within the disk. To investigate grain growth in protoplanetary disks we have obtained multi-wavelength CARMA observations of circumstellar disks in Taurus and Ophiuchus, that constrain the slope of the millimeter dust opacity as a function of radius. We also present an overview of the Paired Antenna Calibration System, which has been employed to obtain observations at high angular resolution with CARMA.

420

Education and Outreach Beyond IYA Oral Session *Room 615/617*

420.01

A Retrospective on the International Year of Astronomy: Lessons Learned

Susana E. Deustua¹, D. Isbell² ¹Space Telescope Science Institute, ²JPL.

2:00 PM - 2:10 PM

Room 615/617

2009 was the International Year of Astronomy, and the Year of Science. Next year, 2011, is the International Year of Chemistry. And undoubtedly, we shall have more International Year of Something Science in the future. Now, almost a year after the International Year of Astronomy, we look back and take stock of the lessons learned, and consider how our experiences can inform those future International Years of X.

420.02

Year 1 of Beyond the IYA2009 in Canada

James E. Hesser¹, J. Bolduc-Duval², D. Crabtree¹, J. Di Francesco¹, R. Lacasse³, D. Lemay³, R. Macnaughton⁴, J. Percy⁵, M. Whitehorne⁴

¹National Research Council, Herzberg Institute of Astrophysics, Canada, ²CEGEP Thetford Mines, Canada, ³FAAQ, Canada, ⁴RASC, Canada, ⁵University of Toronto, Canada.

2:10 PM - 2:20 PM

Room 615/617

1.93M 'Galileo Moments' of personal astronomical discovery through some 3,600 reported events later, the Canadian IYA partnership of amateur and professional astronomers has transitioned to Beyond IYA

activities aimed at solidifying the legacies we hoped to establish. A focus of BIYA in Canada is on reaching out to youth in underserved communities (inner city, Aboriginal, rural) with the support of a three-year grant from the Natural Sciences and Engineering Research Council to our partnership. During 2010 volunteers have continued strengthening relationships with Canadian parks and libraries, partnering with Aboriginal Elders to convey their cultures' stories of the night sky alongside current scientific knowledge, science centers, educators and artists, among others. Salient aspects of the Canadian BIYA efforts will be described.

420.03

Astropix: An Archive of Astronomical Images

Gordon K. Squires¹, R. Hurt¹, C. Rosenthal¹, J. Llamas¹, C. Brinkworth¹, T. Pyle¹ ¹Caltech.

2:20 PM - 2:30 PM

Room 615/617

In fall 2010, a new, central repository of astronomical images became available at http://astropix.ipac.caltech.edu . Enabled by the Astronomy Visualization Metadata (AVM) standard, this archive contains images from NASA's Spitzer Space Telescope, Chandra, Hubble, WISE, GALEX, and the Herschel Space Observatory. For the first time, an automated registry is possible by populating contextual and informational fields in the metadata of the images themselves. This presentation will highlight the features of the archive, how to include your images in the registry and applications enabled including dynamic websites, kiosks, and mobile device applications.

420.04

Leveraging Metadata to Create Interactive Images... Today!

Robert L. Hurt¹, G. K. Squires¹, J. Llamas¹, C. Rosenthal¹, C. Brinkworth¹, J. Fay²

¹Spitzer Science Center/Caltech, ²Microsoft Research.

2:30 PM - 2:40 PM

Room 615/617

The image gallery for NASA's Spitzer Space Telescope has been newly rebuilt to fully support the Astronomy Visualization Metadata (AVM) standard to create a new user experience both on the website and in other applications. We encapsulate all the key descriptive information for a public image, including color representations and astronomical and sky coordinates and make it accessible in a user-friendly form on the website, but also embed the same metadata within the image files themselves. Thus, images downloaded from the site will carry with them all their descriptive information. Real-world benefits include display of general metadata when such images are imported into image editing software (e.g. Photoshop) or image catalog software (e.g. iPhoto). More advanced support in Microsoft's WorldWide Telescope can open a tagged image after it has been downloaded and display it in its correct sky position, allowing comparison with observations from other observatories. An increasing number of software developers are implementing AVM support in applications and an online image archive for tagged images is under development at the Spitzer Science Center. Tagging images following the AVM offers ever-increasing benefits to public-friendly imagery in all its standard forms (JPEG, TIFF, PNG). The AVM standard is one part of the Virtual Astronomy Multimedia Project (VAMP); http://www.communicatingastronomy.org

420.05

WWT Ambassadors: Worldwide Telescope For Interactive Learning Alyssa A. Goodman¹, S. E. Strom², P. Udomprasert¹, A. Valva³, C. Wong⁴ ¹Harvard-Smithsonian, CfA, ²NOAO, ³WGBH Educational Foundation, ⁴Microsoft Research. 2:40 PM - 3:50 PM

Room 615/617

The WorldWide Telescope Ambassadors Program (WWTA) is new outreach initiative run by researchers at Harvard University, WGBH, and Microsoft Research. WWT Ambassadors are astrophysically-literate volunteers who are trained to be experts in using WWT as teaching tool. Ambassadors and learners alike use WWT to create dynamic, interactive Tours of the Universe, which are shared in schools, public venues, and online. Ambassador-created Tours are being made freely available and will ultimately form a comprehensive learning resource for Astronomy and Astrophysics.

In this short talk, we will describe the results of a Pilot Study where volunteer Ambassadors helped sixthgraders use WWT during their six-week Astronomy unit. The results of the study compare learning outcomes for 80 students who participated in WWTA and 80 students who only used traditional learning materials. In the comparison, we find that, after the six-week unit: twice as many "WWT" as "non-WWT" students understand complex three dimensional orbital relationships; and tremendous gains are seen in student interest in science overall, astronomy in particular, and even in using "real" telescopes. Plans for WWTA include expansion to five US sites within the coming year, and ultimately to an International Program. Online materials will ultimately be available through several sites (at WGBH, Harvard and Microsoft), and will be integrated with existing online curriculum programs such as WGBH's Teachers' Domain and Microsoft's Partners in Learning. More inormation is presently available at www.cfa.harvard.edu/WWTAmbassadors/.

421

Evolution of Galaxies IX Oral Session *Room 608*

421.01

New Insights Into the Origin of the Morphology-Density Relation

Peter Erwin¹, D. J. Wilman¹ ¹*MPE, Germany.* 2:00 PM - 2:10 PM *Room 608*

We present an analysis which matches traditional morphological classification of galaxies from the RC3 with a catalog of galaxy and galaxy-group halo masses based on SDSS data; this lets us study the local relations between galaxy morphology (including details such as bar and ring presence) and halo mass. We also investigate how morphology is affected by whether galaxies are "central" or "satellite" systems. The fraction of central galaxies which are ellipticals increases with halo mass, but this is not true for SO galaxies; instead, it is in the satellite galaxies where we find a strong correlation between SO fraction and halo mass.

We also compare our results with predictions from hierarchical, semi-analytic modeling in an effort to test the relevance of different formation channels and bulge-growth models for the distribution of elliptical, S0, and spiral galaxies.

421.02

Finding Dark Galaxies From Their Tidal Imprints Sukanya Chakrabarti¹, F. Bigiel¹, P. Chang², L. Blitz¹ ¹UC, Berkeley, ²CITA. 2:10 PM - 2:20 PM *Room 608* We describe a new method that allows one to determine the mass and relative position (in radius and azimuth) of galactic companions purely from observed disturbances in outer gas disks. We demonstrate the validity of this method by applying it to local spirals with known optical companions, namely M51 and NGC 1512. These galaxies span the range from having a very low mass companion (~ one-hundredth the mass of the primary galaxy) to a fairly massive companion (~ one-third the mass of the primary galaxy). We show that we accurately reproduce the mass and relative position of the companions in these systems, without requiring any knowledge of the optical light from the satellites. This approach has broad implications for many fields of physics and astronomy -- for the indirect detection of dark matter, planetary dynamics, and for galaxy evolution in its use as a decipher for the dynamical impact of cold dark matter sub-structure on galactic disks. Here, we provide a proof of principle of the method by applying it to infer and quantitatively characterize optically visible galactic companions of local spirals, from analysis of observed disturbances in outer gas disks. These findings are significant because until now the detection of dwarf galaxies has primarily relied on the optical light emitted by these systems. Many dwarf galaxies have low light-to-mass ratios, and as such the faint end of this population may well remain undetected. Our method provides a new means of hunting for dark matter dominated dwarf galaxies. The statistical viability of this method could be further clarified by applying it to a large sample of spiral galaxies to determine the incidence of false positives.

421.03

Galaxy Evolution in Sparse Environments Elizabeth Jean Barton¹

¹UC, Irvine. 2:20 PM - 2:30 PM Room 608

The morphology-density relation, or the tendency for dense environments to host early type galaxies with little star formation, extends not only to cluster galaxies, but to all environments including the "field." Thus, clues about the evolution of galaxies can be found in both clusters and in the simplest environments, smal groupings. Using cosmological simulations as a guide, my collaborators and I have developed techniques to measure the properties of galaxies in very sparse systems. We use the Sloan Digital Sky Survey to develop an understanding of processes that remove fuel and suppress star formation in satellite galaxies in these systems, like quenching and "strangulation." Approaching this problem from a different angle, we extend the technique of detecting absorption lines in the spectra of background quasars to study the relationship between low-density gas in the outer halos of galaxies and the environmental and star-forming properties of the galaxies themselves.

421.04

In Search of Quasar Host Galaxies

Jason Young¹, M. Eracleous¹, C. Gronwall¹, O. Shemmer², H. Netzer³, E. Sturm⁴, R. Ciardullo¹ ¹Pennsylvania State Univ., ²University of North Texas, ³Tel Aviv University and Wise Observatory, Israel, ⁴Max-Planck-Intitut fur Extraterrestriche Physik, Germany.

2:30 PM - 2:40 PM

Room 608

We present a study of the morphology and intensity of star formation in the host galaxies of eight Palomar-Green quasars using observations with the Hubble Space Telescope. Accretion-powered and star formation activity have been shown to coincide, motivating us to search for the star-forming regions in the host galaxies of quasars and to determine the star-formation rates. In this work we use calibrated narrow band emission line (H-beta and Pa-alpha) WFPC2 and NICMOS images as maps for total star formation rate. The main challenge in imaging quasar host galaxies is the separation of the quasar light from the galaxy light, especially in the case of z approximately 0.1 quasars in WFPC2 images where the PSF radius closely matches the expected host scale radius. To this this end we present a novel technique for image decomposition and subtraction of quasar light, which we have validated through extensive simulations using artificial quasar+galaxy images. The other significant challenge in mapping and measuring star forming regions is correcting for extinction, which we address using extinction maps created from the Pa-alpha/H-beta ratio. To determine the source of excitation, we utilize H-beta along with [OIII]5007 and [OII]3727 images in diagnostic line ratio (BPT) diagrams. We detect extended line emission in our targets on scales of order 1-2 kpc. A preliminary analysis suggests star formation rates of order 10 solar masses per year.

421.05

Basic Properties of Infrared Galaxies in Cosmological Simulation

Tae Song Lee¹, K. Nagamine¹, J. Choi¹

¹University of Nevada, Las Vegas.

2:40 PM - 2:50 PM

Room 608

Understanding the contribution of infrared (IR) galaxies to the total star formation rate (SFR) is an important topic in galaxy formation. The earlier work by Nagamine et al. (2005) showed a reasonable agreement between cosmological simulations and observations regarding the space density of star-forming galaxies. Here we estimate the IR spectral energy distributions (SEDs) from the simulated high-redshift galaxies by coupling the cosmological SPH simulation output from GADGET-3 with the GRASIL (the population synthesis code by Silva et al., 1998). We compute the luminosity function (LF), galaxy number counts, and redshift distribution in IRAC and MIPS bands of Spitzer observations.

421.06D

Dark Matter Substructure, Galaxy Assembly and Star Formation Histories Vimal Simha¹

¹*The Ohio State University.*

2:50 PM - 3:10 PM

Room 608

We use cosmological SPH simulations to study galaxy growth and the relationship between dark matter halos and the galaxies that form in them. We find that the distinction between central and satellite galaxies in our simulation is weaker than expected in simple models where only central galaxies are able to accrete mass and `receive' mergers of less massive systems. Instead, in our simulation, satellite galaxies continue to accrete gas and convert it to stars after halo mergers with a larger parent halo. Satellites in our simulation are 0.1-0.2 magnitudes bluer than in models that assume no gas accretion on to satellites after a halo merger (instantaneous `strangulation'), which is sufficient to shift galaxies across the boundary from the `red sequence' to the `blue cloud'. Subhalo abundance matching (SHAM) is a technique for assigning luminosities to simulated dark matter substructures by assuming a strictly monotonic relationship between luminosity and halo mass at the epoch of accretion. We carry out Nbody and SPH simulations of a cosmological volume with identical initial conditions, finding that SHAM successfully matches the stellar masses and luminosities of SPH galaxies at a wide range of epochs, albeit with relatively small amounts of scatter. In our SPH simulations that include momentum driven winds, the results are more complex. We examine the relationship between halo assembly and star formation histories with the goal of extending SHAM to a wider domain of observables such as star formation history and colour. In order to guide efforts to fit star formation histories to observed colours or spectra, we investigate parametric fits to the star formation histories of SPH galaxies finding that some commonly used models fail to describe the star formation histories of SPH galaxies but other simple two parameter models achieve greater success.

421.07D

Forming Massive Galactic Disks in LCDM Cosmologies: Challenges and Successes Javiera Guedes¹, P. Madau¹, S. Callegari², L. Mayer²

¹University of California Santa Cruz, ²Institute for Theoretical Physics, University of Zurich, Switzerland. 3:10 PM - 3:30 PM

Room 608

The successful formation of Milky Way-sized disks in cosmological simulations requires the correct treatment of complex baryonic physics at sub-grid scales, particularly gas cooling, star formation, and supernovae feedback. In this talk, I will review some of the challenges that have plagued numerical simulations of flat galactic disks, and will present a detailed comparison between three state-of-the-art cosmological simulations with varying resolution, star formation efficiency, and star formation threshold. I will focus on the effect these parameters on the formation of bar instabilities, the evolution of the baryon fraction with redshift, the properties of the satellites, and the distribution of metals.

422

Elliptical Galaxies: S4G, LIERs, Black Holes Oral Session *Room 607*

422.01

A Spitzer IRAC Study of Massive Quiescent Galaxies in the Early Universe

Elizabeth J. McGrath¹, A. Stockton²

¹University of California, Santa Cruz, ²Institute for Astronomy, Univ. of Hawaii. 2:00 PM - 2:10 PM

Room 607

Fossil studies of massive elliptical galaxies suggest the majority of their stars were formed over a very short period of time early in the history of the universe, however the mechanism by which they assemble their stars remains highly debated. We will present results from a multi-wavelength study of several galaxies at z~1.5 which may be the direct progenitors of the massive galaxy population at lower redshifts. These galaxies have baryonic masses >10¹¹ M_{sun} and stellar populations that already appear to be >1 Gyr old at z~1.5. Rest-frame near-UV spectroscopy indicates that these galaxies are remarkably quiescent, with any current star formation constrained to be $<1 M_{sun}/yr$. Furthermore, using Spitzer IRAC data, we will show how we are able to break the age-metallicity degeneracy that plagues shorter wavelength observations in order to eliminate much of the remaining uncertainty as to the nature of the stellar populations in these galaxies. We use these improved age estimates in conjunction with highresolution morphological data from HST to place these galaxies in context with current models of galaxy formation. Unlike their descendants in the local universe, we find a range in size and morphology, including extremely compact spheroids as well as massive disks of old stars. Very few of these galaxies resemble the typical spheroids that dominate galaxies comprising old stellar populations at the present epoch, indicating that several different mechanisms could be important in building up the most massive galaxies in the universe.

Support for this work was provided by NASA through a Spitzer Space Telescope award issued by JPL/Caltech.

422.02D

On the Origin and Kinematics of the Molecular Gas in Early-Type Galaxies Timothy Davis¹, K. Alatalo², M. Bureau¹, L. Blitz², L. M. Young³, M. Cappellari¹, E. Emsellem⁴, D. Krajnovic⁴, R. M. McDermid⁵, ATLAS-3D Team ¹University of Oxford, United Kingdom, ²University of California, Berkeley, ³New Mexico Tech, ⁴ESO, Germany, ⁵Gemini Observatory.

2:10 PM - 2:30 PM

Room 607

Over the past few years, early-type galaxies have shed their "red and dead" moniker, thanks to the discovery that many host low-level residual star formation. As part of the ATLAS-3D project we are conducting a complete, volume limited survey of the molecular gas in 260 local early-type galaxies with the IRAM-30m telescope and the CARMA interferometer. With this data we are attempting to understand the origin of this molecular gas, and study its distribution, kinematics and star formation properties. We find that around 22% of early-type galaxies in the local volume host molecular gas reservoirs, with central discs, polar structures and rings being common. This detection rate is independent of galaxy luminosity and environment, but does depend on the galaxy kinematics. We find that although the molecular gas extent is smaller in early type galaxies, the linear size scales fairly robustly with the optical and stellar characteristic scale-lengths, independent of the galaxy morphology. The origin of the molecular gas seems to depend strongly on environment, with misaligned gas (indicative of externally acquired material) being common in the field but completely absent in Virgo. I will discuss the origin of the gas in these CO detected galaxies and touch on the implications for the formation and evolution of red sequence galaxies. I will also present kinematic analyses, including the first molecular gas Tully-Fisher relation for early-type galaxies, and show that molecules may be the kinematic tracer of choice for probing the M/L evolution of galaxies over cosmic-time.

422.03

Telling Liers From Liners: The Nature Of The Nebular Emission Of Early-type Galaxies

Marc Sarzi¹, K. Oh², S. Yi², J. C. Shields³, K. Schawinski⁴

¹University of Hertfordshire, France, ²Yonsei University, Korea, Republic of, ³Ohio University, ⁴Yale University.

2:30 PM - 2:40 PM

Room 607

It is now well documented that early-type galaxies (ETGs) are not just passive stellar systems since they often exhibit a relatively weak degree of nebular activity. Such ionized-gas emission is generally characterized by the presence of low-ionization lines, as found in low-ionization nuclear emission-line regions or LINERs.

Recent SAURON integral-field spectroscopic (IFS) observations have shown that the nebular activity of ETGs is always extended and thus requires another source of ionization than a central AGN, most likely old UV-bright stars. In fact, the nuclear LINER emission of ETGs very rarely dominates the integrated nebular spectrum of these systems. This means that in large-scale surveys such as the Sloan Digital Sky Survey (SDSS) where the spectra encompass most of the light from the target galaxies, the LINER-like emission observed in distant ETGs is actually dominated by extended low-ionization emission regions, or LIERs. Such LIERs can have only modest values for the equivalent width of strong emission lines such as [OIII]5007, whereas only AGNs can power the strongest [OIII] emission of true LINERs.

This finding provides an excellent opportunity to further study the nature of such an extended emission, and in particular its source of ionization. The SDSS data offer indeed a much larger array of emission lines that the SAURON IFS data, if a sufficient number of spectra is stacked to bring out the signal of the weak low-ionisation lines.

Using a complete catalogue of SDSS DR7 spectra of morphologically selected ETGs we will present and examine the salient features of the best spectral templates for both the central LINER and extended LIER emission of ETGs.

Stellar Populations And Star-formation Histories Of Early-type Galaxies From The Atlas3d Survey Richard McDermid¹, K. Alatalo², L. Blitz², M. Bois³, F. Bournaud⁴, M. Bureau⁵, M. Cappellari⁵, R. L. Davies⁵, T. Davis⁵, T. de Zeeuw³, E. Emsellem³, S. Khochfar⁶, D. Krajnovic³, H. Kuntschner³, P. Lablanche⁷, R. Morganti⁸, T. Naab⁹, T. Oosterloo⁸, M. Sarzi¹⁰, N. Scott⁵, P. Serra⁸, A. Weijmans¹¹, L. Young¹² ¹Gemini Observatory, ²University of California, ³ESO, Germany, ⁴Laboratoire AIM Paris-Saclay, France, ⁵University of Oxford, United Kingdom, ⁶Max Planck Institut fur extraterrestrische Physik, Germany, ⁷Observatoire de Lyon, France, ⁸ASTRON, Netherlands, ⁹Max-Planck-Institut fur Astrophysik, Germany, ¹⁰University of Hertfordshire, United Kingdom, ¹¹Dunlap Institute for Astronomy & Astrophysics, Canada, ¹²New Mexico Institute of Mining and Technology.

2:40 PM - 2:50 PM

Room 607

Atlas3D is a new survey based on integral-field spectroscopy for a complete, volume-limited sample of 260 early-type galaxies observed within the local 40 Mpc volume - the largest survey of its kind. This Kband selected sample spans a range in mass from 10e10 to 10e12 solar masses, and probes two orders of magnitude in local galaxy density, giving a significantly larger range in mass and environment than previous works of this kind. We present our analysis of the global stellar populations of this sample derived from apertures integrated from our IFU data. These data allow tight control of aperture effects, and give a complete view of the galaxy properties within an effective radius. Trends with mass and other galaxy properties are explored. We find a trend that older galaxies are more compact at a given galaxy mass, and have experienced more rapid star formation at earlier times than younger galaxies of the same mass, as indicated by stellar abundance ratios. This contrasts with a simple picture of downsizing, and suggests additional parameters control the star formation history of these galaxies than only their mass. The trend of size and age is in agreement with recent findings of massive, compact passive galaxies at higher redshifts. We also show preliminary results of non-parametric star-formation histories derived from spectral fitting of our data. These strongly indicate that, despite the presence of young stars and even ongoing star formation, the overwhelming majority of stellar mass in early-type galaxies formed at early epochs, though the assembly into the current systems may have proceeded on different time-scales.

422.05

The Black Hole Mass in M87 from Gemini/AO Observations

Karl Gebhardt¹, J. Adams¹, D. Richstone², T. Lauer³, K. Gultiken², J. Murphy¹, S. Faber⁴, S. Tremaine⁵ ¹Univ. of Texas at Austin, ²Univ. of Michigan, ³NOAO, ⁴Univ. of California, Santa Cruz, ⁵IAS. 2:50 PM - 3:00 PM

Room 607

We present results from an adaptive optics study of the central region of M87 using NIFS on Gemini. The kinematics show a dramatic rise in the velocity dispersion with the AO data. The best-fit dynamical model requires the most massive black hole yet measured with spatially-resolved kinematics at 6.6e9 solar masses. The AO data provides a robust measure of the black hole mass since it so well resolves its sphere of influence. This also allows us to probe the stellar orbital structure reliably, where we find a significant increase in tangential orbital anisotropy. Current and future AO data will provide a significant advance for the field.

Stellar Dynamical Measurements of Black Hole Masses in Brightest Cluster Galaxies

Nicholas J. McConnell¹, C. Ma¹, J. R. Graham¹, K. Gebhardt², T. R. Lauer³, S. A. Wright¹, D. O. Richstone⁴ ¹University of California - Berkeley, ²University of Texas at Austin, ³National Optical Astronomy Observatory, ⁴University of Michigan at Ann Arbor.

3:00 PM - 3:10 PM

Room 607

The black hole mass - luminosity relationship in spheroidal galaxies predicts that the Universe's most massive black holes reside at the centers of Brightest Cluster Galaxies (BCGs). We present the stellar dynamical measurement of the black hole mass in Brightest Cluster Galaxy NGC 6086, plus preliminary measurements for several other BCGs. These are among the most massive and most distant black holes detected with direct dynamical methods. We measured the central stellar dynamics in BCGs using laser guide star adaptive optics and the integral-field spectrograph OSIRIS on the 10-m Keck II telescope. Our measurements will help identify the dominant processes for building giant galaxies at the centers of galaxy clusters, along with their central black holes. Our work is supported in part by the National Science Foundation and the Center for Adaptive Optics.

423

Supernovae IV Oral Session Room 613/614

423.01

Keck Spectra Of z ~ 2 Ultraviolet-Luminous Supernovae: Host Properties, Population III Stars, And The Initial Mass Function At High Redshift

Jeff Cooke¹, M. Sullivan², E. J. Barton³, R. S. Ellis¹

¹Caltech, ²University of Oxford, United Kingdom, ³University of California, Irvine.

2:00 PM - 2:10 PM

Room 613/614

We present 10 spectroscopically confirmed supernovae (SNe) detected in Lyman break galaxies (LBGs) at z = 2.0-2.4. Nine of the 10 spectra exhibit long-lived, luminous rest-frame UV emission features observed in local type IIn SNe, with several spectra showing strong Ly-alpha emission. We investigate the properties of the host galaxies with respect to the ~70,000 monitored r' < 26.5 z~2 LBGs in the survey and find that type IIn SNe are found preferentially in hosts that are fainter and bluer than the median of the full sample.

The remaining event does not display similar emission-line behavior and, in particular, does not show late-time hydrogen emission. The photometric behavior of this extremely luminous event, $M(UV) \sim -21$, is reminiscent of ultra-luminous events recently discovered at lower redshift argued to be pair instability supernovae (PISNe). Because Population III stars are believed to result in PISNe, detections of such events at z^2 , and higher, may provide the first observational examples of Population III stars. Finally, we present an approach that exploits these data to enable the first direct constraint on the form of the stellar initial mass function at high redshift.

The SNe are photometrically detected in the four square-degree fields of the Deep component of the Canada-France-Hawaii Telescope Legacy Survey. Follow-up deep spectroscopy of SN candidates was performed at the W. M. Keck Observatory.

Binary White Dwarf Mergers and Underluminous Supernovae

Mukremin Kilic¹, W. R. Brown¹, S. J. Kenyon¹, C. Allende Prieto²

¹Harvard-Smithsonian Center for Astrophysics, ²Instituto de Astrofisica de Canarias, Spain.

2:10 PM - 2:20 PM

Room 613/614

Short period binary white dwarfs may merge within a Hubble time due to gravitational wave radiation. We have begun a targeted survey to find merging white dwarfs systems, and our first results have tripled the number of known merging white dwarf systems. Our sample includes systems with orbital periods as short as 1 hr and with merger times less than 100 Myr. We will discuss the characteristics of this merger sample and potential links to Type Ia and underluminous supernovae.

423.03

New Constraints on Supernova Explosion Models from Clusters of Galaxies

Renato A. Dupke¹, T. G. M. Estevao²

¹Univ. of Michigan, ²Observatorio Nacional, Brazil.

2:20 PM - 2:30 PM

Room 613/614

The analysis of metal enrichment in clusters of galaxies provides fundamental information to quantify and discriminate enrichment mechanisms such as protogalactic winds, Ram-pressure stripping, as well as heavy element displacement due to nuclear AGN activity in clusters. However, this study has been limited by the uncertainties on SN Type metal yields models. While theoretical models have been advancing at a fast pace, uncertainties can reach factors of two or more for the yields of specific elements for different explosion mechanisms. Since the Intracluster gas is a relatively simple medium from which to extract abundances, one can, in principle, reverse the problem and, assuming that the abundances are well determined, select the best SN explosion models based on measured abundances and their ratios. Here we use metal abundance ratios in a sample of 56 clusters and groups regions, of different temperatures spanning a wide range of values, using ASCA, Chandra and XMM to analyze the models that best fit the data. We find that the 3-D SN Ia model with bubble ignition outperform the other SN Ia models when compared to the observations. We also find that super energetic Hypernovae models agree best with the observations when compared to SN II models, suggesting that a significant contribution of the elements in the ICM (and galaxies) maybe due to Pop III stars.

423.04D

Mixing in Core-Collapse Supernovae

Candace M. Church¹ ¹Los Alamos National Lab. 2:30 PM - 2:50 PM Room 613/614

The observational characteristics of a core-collapse supernova, such as its lightcurve and spectrum, as well as its final nucleosynthesis, are modified by the post-explosion hydrodynamics of the remnant. After a massive star explodes as a supernova, a reverse shock forms and triggers the growth of the Rayleigh-Taylor instability, which mixes together the layers that composed the presupernova star. This mixing determines the final nucleosynthesis of the star, since core-collapse supernovae leave behind stellar remnants in the form of black holes or neutron stars that accrete a certain amount of matter. Detailed multidimensional calculations are required to resolve the Rayleigh-Taylor instability. This thesis presents simulations of the post-explosion hydrodynamics of core-collapse supernovae modeled in two-dimensional (2D) axisymmetric coordinates using the FLASH code, and in 2D axisymmetric and three-

dimensional (3D) Cartesian coordinates using the CASTRO code. Models at zero, 10^{-4} Z_{sun}, and solar metallicity are simulated, at a range of masses from 15 to 40 M_{sun} and explosion energies from 0.5 to 2.4 X 10^{51} ergs. It is found that Rayleigh-Taylor mixing is generally more vigorous in lower mass stars than higher mass stars, in larger, redder stars than more compact bluer stars, and in higher energy explosions than lower energy explosions. For simulations in which the Rayleigh-Taylor instabilities become nonlinear and begin to interact with one another, the final width of the mixed region is the same between 2D and 3D simulations. While the growth rate is initially faster in 3D than in 2D, owing to artificial drag forces arising from 2D geometry, 3D simulations mix more completely, reducing their Atwood number and thus their growth rate relative to 3D. An inverse cascade in the Rayleigh-Taylor instability cannot produce large-scale asymmetries even in 3D; instead, these must arise from the explosion itself.

423.05

Development of Structure in Supernova Simulations From the Explosion out to Late Times

Carola I. Ellinger¹, P. A. Young¹, C. L. Fryer², G. R. Rockefeller² ¹*Arizona State University*, ²*Los Alamos National Laboratory*.

2:50 PM - 3:00 PM

Room 613/614

Detailed and spatially resolved observations of supernova remnants suggest that early in the evolution of the remnant the SN ejecta fragments and forms over-dense knots (Spyromilio et al. 1993). Knots are also observed in the SNRs many years after the explosion (e.g. Moon et al. 2009, Ghavamian et al. 2005, Hammell & Fesen 2008).

We are currently doing numerical simulations of supernova explosions in three dimensions to study the fragmentation of supernova ejecta from the onset of the explosion. We are specifically interested in the formation and development of features like ejecta knots, their physical properties (size, mass, composition, temperature evolution), the factors that influence all those, and in assessing whether these are transient or long-lived features. For the calculations we are using a parallel, 3D Smooth Particle Hydrodynamics code (SNSPH, Fryer et al. 2006), with a small (20 isotope) nuclear reaction network and a radiative cooling routine.

We have performed a number of runs (a spherically symmetric explosion of a 15 Msol star with 1, 10, and 50 million SPH particles, a strong, spherically symmetric explosion of a 16 Msol simulated binary star with 1 and 50 million particles, and two different cases of bipolar explosions for those stars) that were evolved out to at least 1 yr. All scenarios of the 15 Msol explosions show the development of prominent, finger-like structures, that persist at least out to 20 yrs (the end of the longest calculation). These structures are likely due to Richtmyer-Meshkov instabilities that develop as the shock moves through the star. We will be presenting a comparison between the different runs, focusing on the effect of spatial resolution in the calculation, effect of asymmetry on development of structure and resulting altered nucleosynthesis, and effects of timing of adding an asymmetry on the developing structure.

424 *Origin and Evolution of the Milky Way Satellites* Oral Session *Room 604*

424.01

Searching the RCS2 and CFHTLS Surveys for the Faintest Milky Way Neighbors

Beth Willman¹, R. Fadely¹, M. Geha², M. Gladders³, D. Gilbank⁴, H. Yee⁵, B. Sesar⁶ ¹Haverford College, ²Yale, ³University of Chicago, ⁴University of Waterloo, Canada, ⁵University of Toronto, Canada, ⁶Caltech. 2:00 PM - 2:10 PM

Room 604

The ~14 dwarf galaxies around the Milky Way discovered in Sloan Digital Sky Survey (SDSS) data have emerged as the least luminous and most dark matter dominated galaxies in the known universe. SDSS searches for the faintest such objects (e.g. Segue 1, Bootes II, Willman 1, Segue II; L < 1000 L_{sun}) are limited to less than 0.1% of the Milky Way virial volume. It is yet unknown whether they formed with such intrinsically low luminosities or whether tidal forces, due to their proximity to the Milky Way, are to blame for removing stars from these objects. The four extreme satellites found in SDSS may thus be the tip of a large iceberg of such faint systems, or they may indeed be rare objects. To take steps toward overcoming the biases present in our census of Milky Way dwarfs, we are conducting a systematic search of RCS2 and CFHTLS data for resolved Milky Way companions. We present the status of this search, along with the technical challenges of recovering a low-surface brightness stellar population from the sea of unresolved galaxies at faint magnitudes. We show candidates for Segue 1 analogs at 60 kpc < d < 120 kpc, twice as far as reachable with SDSS-depth data for such low luminosity objects. If confirmed, these will be the first ultra-faint Milky Way satellites discovered outside of SDSS data. If ruled out, their study will inform our ongoing and future searches of deep, wide-field data for Milky Way satellites.

424.02D

Mapping the Fossils of the First Galaxies in the Local Volume

Mia S. Bovill¹, M. Ricotti¹

¹Univ. of Maryland.

2:10 PM - 2:30 PM

Room 604

We use a new set of cold dark matter simulations of the local universe to investigate the distribution of fossils of primordial dwarf galaxies formed before reionization around the Milky Way. We find good agreement between the observed stellar properties of a subset of the ultra-faint dwarfs and simulated primordial fossils and propose an upper luminosity threshold for fossils of $10^{6} L_{solar}$. We find the fossils of the first galaxies have galactocentric radial distributions and luminosity functions consistent with observations. In our model, about half of the ~200 luminous Milky Way satellites are preserved fossils, with their fraction decreasing with decreasing galactocentric distance and increasing luminosity. Within the Milky Way virial radius, the majority of fossils have luminosities, $L_V < 10^4 L_{solar}$. However, the simulations produce an overabundance of bright dwarf satellites ($L_V > 10^4 L_{solar}$) with respect to observations. This ``bright satellite problem`` is most evident in the outer parts of the Milky Way. We estimate that although relatively bright, the primordial stellar populations in these halos are extremely diffuse, with surface brightness below SDSS detection limits, and easily stripped by tidal forces near the Milky Way. Although we cannot yet present unmistakable evidence of the existence of the fossils of the first galaxies in the Local Group, the results of our studies suggest at least two robust observational

strategies that can prove stars did form in minihalos with masses less than $10^8 M_{solar}$: i) Deep observations toward nearby isolated dwarfs to detect ``ghost halos'' of ancient stars; ii) The detection of another population of ~ 150 Milky Way ultra-faints with 100-1000 pc half-light radii and luminosities $L_V > 10^4$ Lsolar by future deep surveys. This new population will have minimal trends of stellar velocity dispersion and the maximum circular velocity of the host subhalo with luminosity.

424.03D

Feedback in Milky Way satellites

Sam Geen¹, A. Slyz¹, J. Devriendt¹ ¹University of Oxford, United Kingdom. 2:30 PM - 2:50 PM

Room 604

We use the "Nut" suite of sub-parsec cosmological hydrodynamic resimulations of a Milky Way (MW) like galaxy at high redshift to investigate the formation of MW satellite galaxies, and determine the effect of supernovae feedback on the dwarf progenitors of these satellites and the efficiency of a simple instantaneous reionisation model in suppressing star formation at the low-mass end of this dwarf distribution. By locating galaxies in our high redshift simulation and tracking them to z=0 using a halo merger tree, we can compare our results to present-day observations and comment on whether satellite galaxy formation is complete at high redshift. We find that only the low-mass end of the population of luminous subhalos of the Milky-Way like galaxy is not complete before redshift 8.5, and that although supernovae feedback reduces the stellar mass of the low-mass subhalos ($M \le 10^9 M_{sun}$), the number of surviving satellites around the Milky-Way like galaxy at z = 0 is the same in the run with or without supernova feedback. If a luminous halo is able to avoid accretion by the Milky-Way progenitor before redshift 3, then it is likely to survive as a MW satellite to redshift 0. Finally, we consider a new model for supernova feedback incorporating stellar winds and radiative transfer.

424.04D

Simulations of the Magellanic Stream in a First Infall Scenario

Gurtina Besla¹, N. Kallivayalil², L. Hernquist¹, R. van der Marel³, T. Cox⁴, D. Keres⁵ ¹Harvard Univ., ²Yale, ³STSci, ⁴Carnegie Observatories, ⁵UC Berkeley. 2:50 PM - 3:10 PM

Room 604

Recent high precision proper motions from the Hubble Space Telescope (HST) suggest that the Large and Small Magellanic Clouds (LMC and SMC, respectively) are either on their first passage or on an eccentric long period (≥6 Gyr) orbit about the Milky Way (MW). This differs markedly from the canonical picture in which the Clouds travel on a quasi-periodic orbit about the MW (period of ~2 Gyr). Without a short period orbit about the MW, the origin of the Magellanic Stream, a young (1-2 Gyr old) coherent stream of HI gas that trails the Clouds ~150 degrees across the sky, can no longer be attributed to stripping by MW tides and/or ram pressure stripping by MW halo gas. We propose an alternative formation mechanism in which material is removed by LMC tides acting on the SMC before the system is accreted by the MW. We demonstrate the feasibility and generality of this scenario using an N-body/SPH simulation with cosmologically motivated initial conditions constrained by the observations. Under these conditions we demonstrate that it is possible to explain the origin of the Magellanic Stream in a first infall scenario. This picture is generically applicable to any gas-rich dwarf galaxy pair infalling towards a massive host or interacting in isolation.

Discovery of a Large Stellar Periphery of the Small Magellanic Cloud

David L. Nidever¹, S. R. Majewski¹, R. R. Munoz², R. L. Beaton¹, R. J. Patterson¹, W. E. Kunkel³ ¹Univ. of Virginia, ²Yale University, ³Las Companas Observatory, Carnegie Institution of Washington, Chile.

3:10 PM - 3:20 PM

Room 604

The Magellanic Clouds are a local laboratory for understanding the evolution and properties of dwarf irregular galaxies. To reveal the extended structure and interaction history of the Magellanic Clouds, we have undertaken a large-scale photometric and spectroscopic study of their stellar periphery (The MAgellanic Periphery Survey, MAPS). We present our first results for the Small Magellanic Cloud (SMC): Washington M, T2 + DDO51 photometry reveals metal-poor red giant branch stars in the SMC that extend out to large radii (11.1 kpc), are distributed nearly azimuthally symmetrically (ellipticity=0.1), and are well-fitted by an exponential profile (out to R=7.5 deg). We find a "break" population beyond ~8 radial scalelengths having a very shallow radial density profile that looks to be a stellar halo. The outer stellar distribution contrasts with that of the inner stellar distribution, which is both more elliptical (ellipticity~0.3) and offset from the center of the outer population by 0.63 deg, although both populations share a similar radial exponential scale length. This offset is likely due to a perspective effect since stars on the eastern side of the SMC are on average at closer distances than stars on the western side. The discovery of these new outer stellar structures indicates that the SMC is more complex than previously thought. Our results indicate that it is likely that the SMC has a large stellar halo, which, if correct, would confirm predictions by Lambda CDM simulations that galaxies on all scales should have substructure and halos.

425 *Instrumentation: Space Missions* Oral Session *Room 401*

425.01

Astrometric Detection Exo-Earths with a Small Telescope

Michael Shao¹, R. Goulliard¹, J. Marr¹, B. nemati¹, C. Zhai¹, J. Catanzerite¹, X. Pan¹ ¹JPL.

2:00 PM - 2:10 PM

Room 401

We describe a new concept for space astrometry that enables a 1m class telescope achieve 0.8 uas accuracy in a ~ 1hour observation. The astrometric detection of ExoEarths requires submicroarcsec astrometric accuracy that is very challenging for several reasons. First photon noise of the reference stars means that the product of the telescope aperture and field of view should be at least 1m² and 0.5 deg field of view. A traditional approach to achieving such a large field is to use a TMA telescope.But traditional telescope such as Cassagrain or TMA have a problem called beam walk that can cause milliarcsec of astrometric error over a 0.5 deg field. The other major challenge to sub-microarcsec astrometry over 0.5 deg field is the stability of the very large ccd focal plane. We describe here a new approach to solving these problems that avoids the optical beam walk errors and uses laser metrology to measure the location of the pixels in the focal plane with 1 uas, 100picometer accuracy. Preliminary data from a lab experiment demonstrating subnanometer location of pixels will be discussed.

The Joint Astrophysics Nascent Universe Satellite

Peter Roming¹, D. Fox², D. Burrows², T. Herter³, J. Nousek², J. Kennea², D. Schneider², A. Falcone², JANUS Team

¹Southwest Research Institute, ²Penn State University, ³Cornell University.

2:10 PM - 2:20 PM

Room 401

The Joint Astrophysics Nascent Universe Satellite (JANUS) is a proposed multiwavelength cosmic dawn science investigation. The mission's primary objectives are to: measure the cosmic star formation rate over the redshift range of 5-12, map the growth of massive black holes that seed galaxy formation at z>6, and enable detailed studies of the history of reionization and metal enrichment in the early Universe. Over the baseline mission, the wide-field X-ray Coded Aperture Telescope (XCAT; 1-20 keV) on JANUS is designed to localize high redshift (z>5) GRBs. After a prompt slew, the Near-Infrared Telescope (NIRT; 0.7-1.7 microns) refines the XCAT position by observing the early afterglow of each burst. The position, brightness, and redshift are telemetered to ground-based astronomers in real time. Concurrently, a wide-angle objective-prism survey of the entire extragalactic sky yields detection of high redshift quasars in the 6-10 redshift range.

425.03

IXO Absolute Astrometry Requirements

Michael R. Garcia¹, P. Green¹, R. Smith¹, J. Bookbinder¹

¹Harvard-Smithsonian, CfA.

2:20 PM - 2:30 PM

Room 401

We consider the absolute astrometry requirements for the International X-ray Observatory. These are not to be confused with the requirements for image reconstruction. Some IXO observations will require accurate measurements of the positions of faint x-ray sources to enable high-confidence identifications of counterparts in other wavebands. A common example is identifying the optical or IR counterpart to a distant AGN which is found in an IXO deep or medium deep field. One needs an accurately-determined X-ray determined position in order to find the optical counterpart in a possibly crowed field. A common way to increase the astrometric accuracy of x-ray images is to register the x-ray image to an optical (or IR) frame using a set of previously known optical counterparts. This can be done with Chandra images with up to 0.1 arcsec astrometric accuracy. However this has been done only on selected fields which have been studied in depth at multiple wavebands. Can this technique be used in general, in any field? If so, how many matched objects with what astrometric accuracy is required for a given requirement of absolute astrometric accuracy? Once the registration is complete, what accuracy results? Once large catalogs of AGN are available, from for example eROSITA, we estimate that 5 objects whose IXO measured positions are good to 3 arcsec will be sufficient to register the x-ray image to << 1 arcsec accuracy.

425.04

The Sino-french SVOM Mission For Gamma-ray Burst Studies

Stéphane Basa¹, J. Wei², J. Paul³, S. Zhang⁴

¹Laboratoire D'Astrophysique De Marseille, France, ²NAOC, China, ³CEA and APC, France, ⁴IHEP, China. 2:30 PM - 2:40 PM

Room 401

We present the SVOM mission that the Chinese National Space Agency and the French Space Agency have decided to jointly implement. SVOM (Space-based multi-band astronomical Variable Objects

Monitor) has been designed to detect all known types of gamma-ray bursts (GRBs), to provide fast and reliable GRB positions, to measure the broadband spectral shape and temporal properties of the GRB prompt emission, and to quickly identify the optical afterglows of detected GRBs, including high-redshift ones. In orbit in the second half of the present decade, the SVOM satellite will carry a very innovative scientific payload combining for the first time a wide field X- and gamma-ray coded mask imager for GRB real-time localizations to few arcmin, a non-imaging gamma-ray monitor, and two narrow-field instruments for the study of the GRB early afterglow emission in the X-ray and visible bands. The SVOM payload is complemented by ground-based instruments including a wide- field camera to catch the GRB prompt emission in the visible band and two robotic telescopes to measure the photometric properties of the early afterglow. A particular attention is paid to the GRB follow-up in facilitating the observation of the SVOM detected GRB by the largest ground based telescopes.

425.05

Design Trades for WFIRST

Rolf Danner¹, S. L. Casement¹, C. Lillie¹, A. Lo¹, G. Oleas¹, K. Shapiro¹, C. Spittler¹ ¹Northrop Grumman Corporation. 2:40 PM - 2:50 PM

2.40 PIVI - 2.50

Room 401

The Wide Field Infrared Space Telescope, WFIRST, was recommended as the highest priority mission for the next decade by the National Research Council in their 2010 report "New Worlds, New Horizons in Astronomy and Astrophysics." The mission aims to measure the properties of dark energy via three different techniques: weak lensing, baryon acoustic oscillations and detecting distant supernova explosions. WFIRST will also search for micro-lensing events caused by extrasolar planets, and perform a near infrared sky survey.

Here, we present a fresh look at WFIRST by tracing the science and mission requirements to the three mission concepts that formed the basis of WFIRST and incorporating them into a consistent set. We expect that these requirements will further evolve as NASA evolves the program and use this representative set as an interim solution. From there, we highlight the requirements that are expected to drive the design and evaluate current capabilities based on current and past missions such as the James Webb Space Telescope, the Space Interferometry Mission, and other mission concepts. We ask what makes the project hard to do. What have we learned from other missions that we can bring to WFIRST? Are there any options that would significantly reduce cost or risk while preserving the science return? Finally, we present a preliminary design concept and identify key trades that will lead to a robust, affordable design that meets all science and mission requirements.

We conclude with a preview of future work we expect to perform over the next year.

425.06

An Avalanche Photo Diode for a UV Camera: The Concept and a Progress Report

Melville P. Ulmer¹, R. P. McClintock¹, M. Razeghi¹

¹Northwestern Univ..

2:50 PM - 3:00 PM

Room 401

The current low read noise devices on HST have QEs of about 10%, and Although CCDs can work down to about 200 nm, they suffer from having a read leak even with filters, plus the filters reduce the effective UV efficiency as well. The GaN APD on which we are working can in principle deliver over 50% QE to as short as 150 nm right now, and shorter with improvements. The out of band QE is less that a 0.1%, which means the filters can do their job without the concern of a red leak. We present a progress

report on a single pixel APD with about 25% QE in which even at room temperature the dark induced pulses are almost completely suppressed. This work has been funded in part by NASA.

425.07

The Development And Use Of The HAWAII 2RG Array And SIDECAR ASIC For 1 - 5 Micron IR Observations With A Preview Of The Coming HAWAII 4RG-15.

Donald N. B. Hall¹

¹University of Hawaii.

3:00 PM - 3:10 PM

Room 401

The University of Hawaii - Teledyne Imaging Sensors partnership developed the HAWAII 2RG (H2RG) hybrid array and SIDECAR ASIC specifically for the three near-IR instruments of NASA's James Webb Space Telescope while allowing for broader applications. Key characteristics that have made the H2RG the choice for 1- 5 µm astronomy from the ground and in space are:

1)The 4 Mpxl 2048x2048@18µm format with mosaic buttability.

2)The <0.01 e-/sec dark current and 80 - 90% QE of Teledyne's standard λc ~ 1.7, 2.5 and 5.2 μm MBE HgCdTe.

3)Single CDS read noise ~ 10 rms e- @ 100 KHz.

4)32 channel outputs at ~ 200-400 KHz (16-bit) to 5-10 MHz (12-bit).

5)Reference pixels and guide window.

H2RG arrays, both singly and as small mosaics, are being integrated into JWST instruments and are in operation in numerous ground based telescopes. Much larger mosaics are in the demonstration phase. The SIDECAR ASIC incorporates all the usual control and data handling functions (36 channels) into a single, low-power cryogenic chip that can be co-located in the focal plane while requiring only digital communications, power and a master clock. These characteristics are vital for JWST and future large mosaic focal planes. Although designed specifically for the H2RG, the SIDECAR was successfully adapted to operate the CCDs in the Hubble Space Telescope Advanced Camera for Surveys.

A new HAWAII 4RG-15 (H4RG-15) readout is now in fabrication and characterization of the first hybrid arrays is scheduled for early 2011. The key goal is 16 Mpxl 4096x4096@18µm format at significantly reduced price per pixel over the H2RG. Other augmentations are 64 outputs, improved reference output and pixels and a buttable silicon carbide package by GL Scientific.

NASA's support of the H2RG and SIDECAR programs and NSF's of the H4RG-15 development are gratefully acknowledged.

426 *The Intergalactic Medium as seen by FIREBALL & CW1* Oral Session *Room 609*

426.01D
Performance and Preliminary Results From FIREBALL and CWI.
Mateusz Matuszewski¹, D. Martin¹
¹Caltech.
2:00 PM - 2:20 PM
Room 609
The Faint Intergalactic Redshifted Emission Balloon (FIREBALL) is a balloon-borne, vaccuum ultraviolet (200 nm), fiber-fed integral field spectrograph designed to observe line emission from the intergalactic (IGM) and circumgalactic (CGM) media in the redshift range 0.3 < z < 1.0. It had its first successful

The Cosmic Web Imager (CWI) is a slicer-based integral field spectrograph built for the 200" Hale Telescope at Palomar Observatory. It is designed to detect and map line emission from the IGM, CGM and circum-QSO medium (CQM) in the redshift range 2 < z < 7.

The design, construction, commissioning, and initial scientific results of FIREBALL and CWI are presented.

426.02D

Probing IGM With FIREBALL And CWI Shahinur Rahman¹

¹*California Institute of Technology.* 2:20 PM - 2:40 PM

Room 609

We present overview and initial results from the balloon borne UV instrument FIREBALL and Palomar Hale Telescope instrument CWI. The FIREBALL experiment is designed to search for IGM Ly-a emission at a redshift of 0.7 and other hot gas tracers from z=0.3 to z=1.0. We report on the data and initial science results from our flight in June, 2009. CWI is an integral field spectrograph which probes the strong, redshift UV resonance lines of Ly α 1216, CIV 1550, and OVI 1033 over 3600-9000 Å to trace IGM at 1 < z < 7.

426.03

The Keck Cosmic Web Imager: A Facility Instrument for Low Surface Brightness Astronomy Patrick Morrissey¹, KCWI Team

¹Caltech.

2:40 PM - 2:50 PM

Room 609

The Keck Cosmic Web Imager is a new 2-channel integral field spectrograph being designed for observations of low surface brightness sources in the IGM. It will employ a classical image slicer integral field unit with exchangeable slicer units for added flexibility. We will present the KCWI preliminary design, which is based on an existing spectrograph now in regular use at the Palomar 200" telescope. KCWI will offer enhanced performance as a result of dual band optimization, low noise blue and deep-depleted red CCDs, as well as a robot-driven grating exchanger.

426.04

The IGM Project: Searching For IGM Emission Over 0<z<4 With FIREBALL And CWI

Christopher D. Martin¹, M. Matuszewski¹, S. Rahman¹, P. Morrissey¹, A. Moore¹, D. Schiminovich², B. Milliard³, S. Frank³, J. Deharveng³, C. Peroux³, CWI Team, FIREBALL Team, KCWI Team, ISTOS Team ¹Caltech, ²Columbia University, ³Laboratory Astrophysique Marseille, France. 2:50 PM - 3:00 PM

2.50 PIVI - 5.00

Room 609

I discuss several experimental projects underway or proposed designed to discover and map emission from the IGM. The Cosmic Web Imager (CWI) is a ground-based high resolution spectrometer designed to detect low surface brightness emission from redshifted Lyman alpha, OVI and CIV at Palomar and Keck Observatories, over 2<z<7. FIREBALL is a balloon-borne telescope/spectrometer that is searching for IGM emission in the 0.3<z<1.0 range in the UV balloon window at 200 nm. ISTOS is a proposed mission to discover and map baryons in the IGM in the space UV. I will report on preliminary results from FIREBALL and CWI. This work is supported by NASA and NSF. **427** *Star Associations, Star Clusters III* Oral Session *Room 606*

427.01D

MASSCLEAN - MASSive CLuster Evolution and ANalysis Package - A New Tool For Stellar Clusters Bogdan Popescu¹

¹University of Cincinnati.

2:00 PM - 2:20 PM

Room 606

For many Milky Way clusters it is difficult to be observed because they are obscured by the dust in the disk of our Galaxy. The clusters from the Local Group and beyond are too distant, so only their integrated properties could be used most of the time. There is one way to analyze the observational data, to search for clusters, and to describe them: simulations.

MASSCLEAN (**MASS**ive **CL**uster **E**volution and **AN**alysis) package was developed to provide a better characterization of Galactic clusters, to derive selection effects of current surveys, and to provide information about the extra-galactic clusters.

Simulations of known Galactic clusters are used to get better constraints on their parameters, like mass, age, extinction, chemical composition, distance. This is the *traditional* way to describe the Galactic clusters, fitting the data using the available models. The difference is that MASSCLEAN simulations provide a consistent set of parameters.

The majority of extra-galactic clusters are known only from their integrated properties. The current models for stellar populations are available only in the *infinite mass limit*. But the real clusters have a finite mass, and their integrated colors show a large dispersion (stochastic fluctuations). The description of the variation of integrated colors as a function of mass and age lead to the creation of

MASSCLEAN*colors* database, based on 70 million Monte Carlo simulations. Since the database entries form a consistent set of integrated colors, integrated magnitudes, age and mass, they can be used to improve the current age and mass determinations. The accuracy could be improved only by solving for age and mass together, and this is done by MASSCLEAN*age*. The results for over 900 clusters provide a new look to the LMC cluster population and could be used to study the possible mass dependence of cluster lifetime, dissolution time and infant mortality.

427.02

Detailed Spectroscopic Abundance Analysis in Praesepe

Steven J. Margheim¹, C. Jones²

¹Gemini Observatory, Chile, ²University of Tasmania, Australia.

2:20 PM - 2:30 PM

Room 606

We are conducting an investigation of solar-type stars with high-SNR, high-resolution echelle data to understand the effects and limits of modern spectroscopic abundance analysis techniques. I will discuss our results and their implications.

427.03D

The Initial Conditions and Evolution of Open Clusters: Dynamical Evolution Joseph M. Converse¹

¹*University of Toledo.* 2:30 PM - 2:50 PM

Room 606

Despite being some of the most familiar objects observed in the sky, much remains unknown about open clusters. The theory of their formation admits many unanswered questions, and the complex dynamics of their evolution remains an extremely difficult problem to address. In this thesis, I present results that both help to constrain formation theories, as well as to shed new understanding on the many physical processes that drive their evolution.

Utilizing a series of N-body simulations, I argue that gravitationally bound stellar clusters of modest population evolve very differently from the picture presented by classical dynamical relaxation theory. The system's most massive stars rapidly sink towards the center and form binary systems. These binaries efficiently heat the cluster, reversing any incipient core contraction and driving a subsequent phase of global expansion. Most previous theoretical studies demonstrating deep and persistent dynamical relaxation have either conflated the process with mass segregation, ignored three-body interactions, or else adopted the artificial assumption that all cluster members are single stars of identical mass. In such a uniform-mass cluster, binary formation is greatly delayed, as I confirm here both numerically and analytically. The relative duration of core contraction and global expansion is effected by stellar evolution, which causes the most massive stars to die out before they form binaries. In clusters of higher N, the epoch of dynamical relaxation lasts for progressively longer periods. By extrapolating my results to much larger populations we can understand, at least qualitatively, why some globular clusters reach the point of true core collapse.

427.04

Candidates for Young Super Star Clusters in the Milky Way

Mubdi Rahman¹, C. D. Matzner¹, D. Moon¹

¹University of Toronto, Canada.

2:50 PM - 3:00 PM

Room 606

Massive Star Clusters ($M > 10^4 M_{\odot}$) have been known to exist throughout the local Universe, but few such objects have been found within our own Galaxy. These clusters the majority of the galactic OB star formation, and thus dramatically alter their surroundings through winds, ionizing flux and radiation pressure, and supernovae, eventually destroying their natal clouds and inflating superbubbles which will erupt from the Galactic plane. We search for the young stellar clusters within the star forming complexes identified by Rahman & Murray (2010) using the WMAP free-free and Spitzer GLIMPSE 8 micron observations. Located far across the Galactic plane, these clusters are highly extinguished and crowded by field stars. Using the 2MASS catalogue, we have developed a method of identifying overdensities of sources with colours consistent with the extinguished upper main sequence coincident with the star forming complexes. The difficulty in this method comes from the large number of overlapping foreground sources in comparison to the expected number of cluster sources in any given candidate cluster. We identify a candidate for the most massive young cluster in the Galaxy ($M \sim 10^5 M_{\odot}$), which we have dubbed the Dragonfish Cluster. The candidate cluster is at a distance of 9.7 kpc and has a total ionizing luminosity of 7×10^{51} photons s⁻¹. We identify nearly 400 OB star candidates associated with the cluster, to be confirmed with near-infrared spectroscopy.

427.05D

Get A Bite On The "Delicious" Young Star Cluster NGC 3603

Xiaoying Pang¹, E. Grebel¹, M. Altmann¹, A. Pasquali¹

¹Astronomisches Rechen-Institut, Heidelberg University, Germany, Germany. 3:00 PM - 3:20 PM

Room 606

Young star cluster NGC3603 is one of the most massive star clusters in the Milky Way. It hosts 10 times more OB stars than the Orion Nebular Cluster, among which two are the most massive binaries in the Galaxy (Schnurr et al. 2008). To investigate this star formation arena, we utilize the HST/WFPC2 data. Those data are 10 years apart, which permits us to determine star membership. The cluster displays a significant degree of mass segregation (Pang et al. 2010). To quantify the lower limit in stellar mass at which we see segregation, we apply the minimum spanning tree analysis to cluster stars. The result shows that the stars above 5 solar mass exhibit pronounced mass segregation. What's the origin of this mass segregation? Simulations by Moeckel & Bate (2010) show that primordial segregation is transient and exists within the first 1 Myr. The cluster pre-main sequence (PMS) stars display an age spread up to 3 Myr, while the main sequence stars are consistent with an age of 1 Myr (Pang et al. 2010). And Beccari et al. (2010) derive an age spread as large as 10 Myr among PMS stars. Therefore, at present, the age of NGC3603 is still highly uncertain. A way to improve the age determination of the cluster is to quantify the differential reddening across the cluster. The differential reddening is about 0.8 mag from the core of NGC3603 to the outer region (Sung & Bessel 2004). This affects the PMS stars, which are spatially distributed more widely than the MS stars. We are currently deriving an extinction map of the cluster through H_{alpha} and Paschen_{beta} images from WFC3 (work in progress), in order to correct the color magnitude diagram, and thus to better constrain the age of the cluster and the masses of its members.

Thursday, January 13, 2011, 3:40 PM - 4:30 PM 428

Berkeley Prize: Kepler: Opening New Doors in Astronomy Invited Session Ballroom 6AB

428.01

The Kepler Mission: From Concept to Operations David G. Koch^1

¹NASA Ames Research Center. Ballroom 6AB

From concept to launch and operations, what became the Kepler mission took a guarter of a century to create. We will review some of the steps along the way, the challenges, opportunities, strategic decisions and choices that had to be made that resulted in a mission that has the capability to detect and determine the frequencies of Earth-size planets in or near the habitable zone of solar-like stars. The process of going from starlight focused onto individual pixels to declaration of a planet detection is long and complex. Data for each star are recorded on the spacecraft and telemetered to the ground once per month. The raw pixel data are processed to produce light curves for each star. The light curves are processed to search for sequences of transits. A team of scientists examines the output to decide which meet the many validation criteria and qualify as candidates. Next an extensive series of ground-based follow-up observations are performed on the candidates now numbering in excess of 700. The objective is to eliminate false positive cases, while simultaneously improving our knowledge of the parent stars. Extensive analysis and modeling is performed on both the original photometric data and the newly acquired ground-based data to ascertain the true nature of each candidate. On the order of one-quarter to one-half of the candidates are rejected, mostly as some form of eclipsing binary. Of the remaining, some meet all the criteria and are submitted by the science team for peer-reviewed publications. Others may just require more data or may be left as undecided candidates for future research. An extended mission beyond 3.5 years will significantly improve the results from the Kepler mission, especially by covering the outer portion of the habitable zone for solar-like stars.

428.02 Kepler Mission: An Overview of Science Results William J. Borucki¹

¹NASA Ames Research Center.

Ballroom 6AB

Analysis of current Kepler observations show the presence of over 700 candidate planets, 1800 eclipsing binary stars, and variable stars of amazing variety. Many of the planetary candidates are smaller than Neptune. Several of the larger candidates are found in the habitable zone of the host stars. Candidates as small as Earth in short period orbits are being detected. Discoveries of eight exoplanets are shown including one star with three transiting planets. The candidates and the announced planets are compared with known exoplanets with respect to mass, size, density, and orbital period. In addition to radial velocity measurements, the observed gravitational interaction between planets in near-resonant orbits is being used to determine planet masses. Asteroseismic analyses of the Kepler stars provide a wealth of information on both main sequence and evolved stars. Highly accurate values for stellar and planet sizes have been derived. Measurements of stars in the star clusters in the field-of-view are underway to extend the rotation rate versus age relationship to gigayear ages.

Author Index

-H Chen, H. 340.14 -T Lee, H. 340.14 A'Hearn, Michael F. 220.04, 306.07, 306.08, 349.04 A'Hearn, M F. 435.05 Aalto, Susanne 246.11 Aarnio, Alicia 340.22 Abajian, Mark 142.43 Abate. Alexandra 252.19 Abdo, Aous 105.06 Abel, Paul A. 252.10 Abrahams, Peter 111.05 Abramson, Anne 115.01D ACCEPT team, 149.08 Accetta, Katherine 150.01 Accetta, Katharine 152.03 Accomazzi, Alberto 116.08, 145.01 Acquaviva, Viviana 407.04 Adams, Elizabeth R. 306.05 Adams, Joshua 325.01D, 407.09, 422.05 Adams, Joseph D. 157.04, 340.04 Adams, J D. 340.13 Adams, Joshua J. 151.02, **403.03D** Adams, Scott 152.38 Ade, Peter 313.05 Aerts, C. 103.07 Afonso, Cristina 253.02 Afsar, Melike 153.08 AGES, 246.06 Agol, Eric 253.06, 343.02, 343.13, 402.08 Agrawal, Avinash 240.05 Agudo, Ivan 212.01, 408.04 Agueros, Marcel 153.06, 153.07 Agueros, Marcel A. 153.05 Aguilar, Alejandro 256.05 Aguirre, James 151.03, 244.02, 432.06 Agustsson, Ingolfur 403.01 Ahmad, Zarah 252.07, 252.08, 252.18, 252.21, 252.25 AIA Team, 155.09 Ake, Tom 254.01 Ake, Thomas B. 254.03 Akeson, Rachel L. 220.05 Akhlite Al-Baidhany, Ismaeel Ahdulla 246.09 Alardin, William Henry Lee 157.07

Alatalo, Katherine 422.02D 422.04 Alatalo, Katey Alatalo, Katherine A. 335.08 Albert, Loic 418.08 Alcock, Charles 116.01, 435.06 Alcolea, Javier 256.02 Aldcroft, Tom 125.07, 142.17 Aldcroft, Thomas L. 310.04 Aldering, G. 249.09 Aldering, G 249.10 Aldering, G. 308.01 Aldering, Greg 308.04, 308.05D Aldering, G 337.13 Alencar, Sylvia H. P.. 253.10 Alessandra, Aloisi 254.28 Alexander, Kate 335.11 Alexander, Michael J. 258.25 ALFALFA Team, 115.03, 149.28, 149.29, 149.30 255.04, 255.15 Ali, Babar Ali, Nancy 158.09 Ali-Haimoud, Yacine 231.05D Allam, Sahar 347.01, 347.02 Allam, Sahar S. 245.12, 347.03 Allan, John 246.20 Allen, Bruce 234.01, 234.05 Allen, Bill 338.14 Allen, Glenn E. 256.17 Allen, Jessamyn 343.21 Allen, James T. 233.03D Allen, Lori 255.15, 258.15, 258.16, 258.21 Allen, L E. 340.13 Allen, Lori E. 434.43 Allen, Peter 242.09 Allen, Rick 433.09 Allen, Tom 258.19 Allen Telescope Array Team, 240.01, 240.02, 240.03, 240.04, 240.06, 240.07 Allende Prieto, Carlos 423.02, 434.30 Aller, Hugh 142.24, 142.65 Aller, Hugh D. 142.41, 142.47 Aller, Margo 142.24, 142.47, 142.65, 212.01 Aller, Margo F. 142.41 Allers, Katelyn 242.27 Allers, Katelyn N. 307.01, 340.28 252.13 Allison, Idatonye J. Allison, Richard J. 152.09 Allyn Smith, J. 245.12

Almgren, Ann S. 234.03D Alna'Washi, Ghassan 256.05 Aloisi, Alessandra 254.01, 254.04, 337.18 P243.28 Alper, Basak 242.11, 242.17 Alpert, Naomi 156.05, 341.01 AlSayyad, Yusra 432.12 Altamirano, Diego Altmann, Martin 427.05D Amanullah, R. 249.09 Amanullah, R 249.10 Amanullah, Rahman 308.05D Amblard, Alexandre 249.04 Amezcua, Maira M. 142.26 Ammons, Stephen 413.06 An, Deokkeun 434.49 and LSNEP team, 430.33 Anders. Peter 312.02D Andersen, Morten 258.27 Anderson, David 234.01 Anderson, David R. 402.02, 418.02 Anderson, Jay 152.16, 152.20, 152.21, 152.22, 152.23 Anderson, J. 152.24 Anderson, Jay 152.25, 152.26, 152.27, **254.24**, 303.04, 415.06, 434.18 Anderson, Loren D. 132.01, 132.02 Anderson, L. D. 132.03 Anderson, Marin 240.03 Anderson, Michael 417.05 434.13 Anderson, Marin M. Anderson, Scott 142.16, 142.17 Anderson, Scott F. 125.07, 230.01, 230.02 Anderson, S. F. 252.17 Anderson, Scott F. 430.13 Andersson, B-G 251.22, 434.34 Andersson, K. 149.15 Andrew, John R. 252.05 Andrews, Jennifer 337.22 Andrews, Jennifer E. 112.02D Andrievski, Sergei 342.17 Andropoulos, Jenny 146.05 Angelakis, Emmanouil 142.01, 142.02 Angione, John 340.24 Anglada-Escudé, Guillem 340.12 Anglada-Esqude, Guillem 429.07 ANGST team, 328.01 Aniano, Gonzalo 202.07 Annis, James 213.06, 239.03, 347.02

Annis, James T. 433.16 Ansari, Reza 252.19 Anthony-Twarog, Barbara 153.10 Antilogous, P 337.13 Antilogus, P. 308.01 Antilogus, Pierre 308.04 Antonelli, Angelo 108.04 Antonow, Alex 248.10, 342.03 Antonsen, Adrienne 415.01 Antonucci, Robert 230.04 AO Arp 220 Team, 332.01 Aoki, Wako 434.48 Apai, D. 340.19, 340.29 APEX-SZ Collaboration, 227.03D Appleton, Philip 115.04 Appleton, Philip N. 255.08, 335.27 308.01 Aragon, C. Aragon, Cecilia 308.04 Aragon, C 337.13 Aragona, Christina 105.01D Arai, Toshiaki 249.03 Arav, Nahum 432.02, 432.03 Aravena, Manuel 335.21 130.04D Araya, Miguel Arce, Hector 434.33 Arce, Héctor G. 258.12 Arce, Hector G. 258.13 Ardavan, Arzhang 336.01 Ardavan, Houshang 234.06, 336.01 Arecibo Galaxy Environment Survey (AGES), 254.18 Arendt, Richard G. Arimoto, Nobuo 434.48 Arion, Douglas N. 248.03 Arkenberg, Keith 155.06 344.16 Armstrong, Amber Armstrong, John C. 220.07 Armstrong, J. T. 242.06 Armstrong, Robert 334.03 114.07 Armus. L. Armus, Lee 255.08, 333.06 Arnold, Rachel L. 149.12 Arnold, Timothy 340.25 Aros, Jon C. 346.11 Arraki, Kenza S. 142.17 Arrant, David J. 250.11 Arribas, Santiago 254.27

149.23

Artymowicz, Pawel 253.10 Arvidsson, Kim 258.25 Asahi, Takeshi 344.13 Ashby, Matt 230.04 Ashcraft, Teresa 337.20 ASKAP. 334.06 Aspin, Colin 340.16 333.15 Assef, Roberto 240.05 ATA SonATA Team, Atacama Cosmology Telescope Collaboration, 313.03 407.07, 407.08 Atek, Hakim Athanassiadou, Themis 337.06, 341.09 ATLAS 3-D Team, 335.08 ATLAS Consortium, 245.14 ATLAS-3D Team, 422.02D Atlee, David W. 213.04D Atri. Dimitra 319.05D Auger, Matt 430.05 Auger, Matthew W. 225.01, 252.22, 430.01 Aulbert, Carsten 234.01 Axelrod, Tim 252.01, 334.11 Ayres, T. 340.19 Ayres, T 340.29 154.06 Ayres, T. R. Ayres, Thomas R. 154.07, 340.34 Babcock, Bryce A. 306.05 Babler, Brian 241.14, 241.16 Babul, Arif 109.06 Backer, Don 432.06 Backus, Isaac 336.03 Bacon, Greg 251.16 Badenes, Carles 337.32 Baggett, Sylvia 254.16, 254.37, 254.39 Bahcall, Neta A. 222.06 Bai, Lei 325.03 Bai, Zhongrui 334.13 Bailey, J E. 433.24 Bailey, James E. 436.03 Bailyn, Charles 126.04, 408.01, 432.14 Bailyn, C. D. 143.04 Bailyn, Charles D. 144.20 Baines, E. K. 242.06 Baines, Ellyn K. 343.07 Bains, Indra 113.04 Baker, Andrew 202.09 Baker, Andrew J. 245.12, 309.01D, 334.14, 335.46, 433.17 Baker, K.K. 344.08 Baker Big-Back, Clarice 209.05 Bakos, Gaspar 253.01, 253.02 Balasubramanian, Kunjithapatham 254.06 Balazinska, Magdalena 344.12 Baldwin, Jack 233.03D Balick, Bruce 256.02, 256.06, 256.07, 256.08, 256.09 Ball, Nicholas M. 344.03 Ballantyne, D. R. 252.17 Ballard, Sarah 220.04, 258.15 Ballouz, Ronald-Louis 242.28, 343.12 258.02, 258.03, 258.26, 340.20, 411.03D Bally, John Balog, Z 202.03 Balonek, Thomas J. 142.09, 142.10 258.29 Balser, Dana Balser, Dana S. 132.01, 132.02, **132.03**, 251.02 Baltay, Charles 126.04, 241.17 Baltay, C. 308.01 Baltay, Charles 308.04 Baltay, C 337.13 Baltay, Charles 433.18 Bamford, Steven 106.04 Bañados, Eduardo 149.02 Banados, Eduardo 149.17 Bandyopadhyay, Reba M. 338.18 Banerjee, Robi 434.36 Bangert, John 344.14 Bania, Thomas M. 132.01, 132.02 Bania, T. M. 132.03, 251.02 Bankert, Justin 213.01, 252.07, 252.08, 252.18 Bankert, Justine 252.21 Bankert, Justin 252.25 Baptista, Brian J. 430.24 Barai, Paramita 142.48 Barajas, Tzitlaly 156.12 Baranec, Christoph 157.11, 433.14 Barba, Rodolfo 147.02 Barbary, K. 249.09 Barbary, K 249.10 Barbary, Kyle H. 308.05D Barber DeGraaff, Regina 149.24 Bard, Christopher 342.14 Bard, Deborah 252.07, 252.08, 252.18, 252.21, 252.25 Barenfeld, Scott 142.62 Barentine, John 257.05 Barentine, J. B. 157.17

Barger, Amy 326.03 Barger, K. A. 251.04, 251.07 Barger, K A. 251.09 Baring, Matthew 212.03 Barker, Thurburn 334.01 Barkhouse, Wayne 125.07, 149.03, 149.10 Barkhouse, Wayne A. 310.04 Barkhouser, R. H. 433.12 Barlev, Maya 147.17 Barlow, Michael 337.22 Barlow, Tom A. 142.30 Barman, Travis 302.01, 343.06, 418.04 Barman, Travis S. 343.08, 418.05 Barmby, Pauline 434.19 Barnes, Jason W. 429.03 Barnes, Kate L. 147.11 Barnes, K. L. 147.12 Barnes, Kate L. 417.03 Barnes, Rory 220.07, 253.06, 343.22, 402.06, 415.01, 415.03 Barnes, Stuart 413.07 Baron, E. 337.03 337.17, 434.24 Baron, Eddie Baron, Fabien 257.03 Barott, William C. 240.03 Barr, Jeffrey D. 252.05 Barrau, Aurelien 252.19 Barret, Didier 432.17, 432.25 Barrett, Paul 344.14 Barrientos, L. 249.09 Barringer, Daniel 349.07 Barron, Eric G. 344.14 Barron, Kamira 249.13 Barrows, Robert S. 430.12 Barry, D. J. 254.21 Barry, Don J. 254.22 Barry, Richard K. 349.04 Barsony, Mary 113.02 Barth, Aaron J. 106.07 Barth, A. J. 252.17 Barth, Aaron J. 310.08 Barthel, Peter 230.04 Barthelemy, Ramón 148.07 Bartlett, David F. 231.07 Bartlett, Jennifer L. 146.06, 158.07, 344.14 Bartlett, Meredith 241.15 Barton, Elizabeth J. 147.03, 412.05, 421.03, 423.01

Basa, Stéphane 425.04 Basri, Gibor 201.05 Bassa, Cees G. 144.24 Bastian, Nate 152.35 Bastien, Fabienne 434.31 Bastien, Pierre 251.22 Basturk, Ozgur 140.18 Basu-Zych, Antara 245.15 Batalha, Natalie 140.05 Batalha, Natalie M. 103.04, 140.04, 140.21 Battaglia, Nicholas 109.03D Battersby, Cara 258.02, 258.03, 411.03D Battisti, Andrew 338.11, 349.02 Battle, John 249.02 Baubock, Michi 251.21 Bauer, Franz E. 434.26 Baumgartner, Wayne 326.02D Baumgartner, Wayne H. 125.01, 434.01 Baumont, Sylvain 252.19 Bavarsad, Ernest 152.36 Bayliss, Daniel 253.02 Bayliss, Matthew 213.02D Bazin, Gurvan 334.03 Beacom, John F. 337.28 Bean, Jennifer 153.01 Bean, Jacob 343.11, 418.06 Beaton, Rachael 158.05 Beaton, Rachael L. 424.05 Beaudet, Carla 344.10 Beaumont, Christopher 217.01 Bebek, Christopher J. 433.02 Beccari, Giacomo 258.27 Beck, Sam 337.23 Beck, Tracy 254.17, 254.27 Becker, Andrew 142.63, 242.13, 252.13 Becker, Andrew C. **252.12**, 253.06, 430.16 Becker, George 114.04 Becker, Matthew 213.06 Becker, Peter A. 142.61, 215.06D Becker, Robert H. 106.01, 347.04 Beckwith, Kris 322.01 Bedell, Megan 340.15, 340.27 Beeler, Daniel J. 434.30 Beerman, Lori 152.19 Beers, Timothy 242.12, 334.12 Beers, Timothy C. 241.10, 252.15, 334.13, 434.49 Begum, Ayesha 241.01, 241.02, 241.03, 241.04, 241.06 Behkam, Razieh 108.05D Behm, T. W. 433.09 Beichman, Charles 253.14, 413.05D Beichman, Charles A. 220.05, 253.13 Beirão, Pedro 255.08 Bejnood, Alborz 337.23 Beklen, Elif 434.01 Beky, Bence 253.02 Beland, Stephan 254.03 Béland, Stéphane 254.28 Belikov, Ruslan 254.06 Bell, John B. 234.03D Bell, Keaton 335.33 Bell, Steve 158.07 Bellinger, Earl 342.04 432.12 Belloni, Tomaso M. Bellovary, Jillian M. 128.01D Beltran, Maite 255.03 Belur, Atul 201.03 Bemis, Ashley 331.03 Bender, Amy N. 227.03D Bender, Chad 253.04, 253.09, 401.01, 401.02 Bender, Peter L. 225.05 Benedict, G. F. 152.40, 242.25, 415.01 Benford, Dominic 313.05, 333.04, 333.11, 333.12, 333.14 Benford, Dominik 333.15 Benford, Dominic J. 229.04, 254.12, 333.19 Benitez, Narciso 109.05 Benjamin, Robert 241.16, 246.21 **241.14**, 251.06, 251.08, 251.28, 251.30 Benjamin, Robert A. Bennert, Vardha 142.08 Bennert, Vardha N. 310.04 Bennett, Alice 340.02 Bennett, Charles 313.05 Bennett, David P. 318.01 432.06 Benoit, Erin Benson, Andrew J. 231.03 Bentz, Misty 246.09 Berdyugin, Andrei 434.34 Berendsen, Marni 158.01 Beresnyak, Andrey 217.05 Berg, Leonard J. 433.25 Berger, Edo 141.02, 141.03 Bergeron, Pierre 341.01 Bergin, Edwin 255.15

Bergin, Edwin A. 217.07 Bergman, Marcel 337.32 Berke, Daniel 258.31 Berke, Martin 342.18 Berlind, Andreas 249.06 Berlind, Andreas A. 249.07, 249.08, 334.14, 334.15 Bernard-Salas, J. 254.21 Bernard-Salas, Jero 254.22 Bernardi, Gianni 116.07 Berndsen, Aaron 334.06 Bernstein, Gary 227.01, 227.02 Bernstein, Rebecca 109.05, 152.37 Bernstein, Rebecca A. 328.04D Berry, Michael 250.08 Berry, Michael J. 407.02 Berta, Zachory K. 343.11 Bertin, Emmanuel 334.03 Bertin, Giuseppe 152.10 Bertness, Kris 254.19 Bertoldi, Frank 430.11, 430.28 Beshore, E 334.17 Besla, Gurtina 424.04D Bessell, Michael S. 322.05 Besuner, Robert W. 433.02 Beuther, Henrik 416.03D Bhat, N D. R. 234.01 Bhat, P. N. 434.01 Bhat, Ramesh 234.05 Bhattacharjee, Anirban 142.04 Bhattacharya, Suman 109.04D, **127.04** Bhatti, Waqas 226.03 Bianco, Federica 308.07 Bickerton, Steve 152.23 Bigelow, Bruce C. 157.07 Bigiel, Frank 246.14, 421.02 Bildfell, Chris 109.06 Bildfell, Chris J. 308.06 Bildsten, Lars 126.01D, 341.08 Bilikova, Jana 339.14 Biller, Beth 431.01, 434.13 Biller, Beth A. 253.10 Billot, Nicolas 202.02 Bilodeau, Rene C. 256.05 Bilty, Katherine 349.06 Binder, Breanna A. 430.13 Biretta, John 254.16
Birkinshaw, Mark 230.04 Birkmann, Stephan 254.27 Bisol, Alexandra 338.07 Biswas, Rahul 252.20 Biwer, Chris 139.08, 336.12 Bizyaev, Dmitry 246.03, 335.49 Bjorkman, Jon E. 339.22 Bjorkman, Karen S. 339.21, 339.22, 339.24 Blaha, Cindy 251.12 Blain, Andrew 333.13, 333.14, 430.28 Blair, William 254.17 Blair, William P. 256.21, 256.22, 256.32 Blais, Eric 324.03 Blake, Chris 204.01 Blake, Melvin 434.02 Blakeslee, John 312.03 Blakeslee, John P. 149.24 Blanc, Guillermo 407.09 Blanc, Guillermo A. 149.20, 233.04, **325.01D**, 403.03D Blanco Cosmology Survey, 334.03 Blank, D. L. 343.25 Blanton, Michael 249.06, 430.09 Blanton, Michael R. 229.01D Blatnik, Michael 344.10 Blecic, Jasmina 402.02, 418.02 Blevins, Sandra 333.06 Blevins, Sandra M. 335.20 Blitz, Leo 335.08, 421.02, 422.02D, 422.04 Blondin, Stephane 337.32 Bloom, Joshua 157.07 Bloom, Joshua S. 108.02D Bloom, Josh S. 142.49 Bloom, J. S. 252.01 Bloom, Josh S. 252.12 Bloom, Joshua S. 434.30 430.22 Bluck, Asa 105.02D Blum, Jennifer L. Blum, Robert 252.03 Blum, Robert D. 153.15 Blundell, Katherine 335.39 433.17 Blyth, Sarah Bochanski, J. 252.14 Bochanski, John 252.15 Bochanski, John J. 242.02, 242.19, 307.03, 343.14, 434.11 Bock, James 244.02 Bock, Jamie 249.03

Bock, James J. 249.02 Bock, Oliver 234.01 Bockelee-Morvan, Dominique 156.03 Bode, Tanja 432.15 Boden, Andrew F. 220.05 Bodenheimer, Peter 307.06 Boeker, Torsten 246.05, 254.27 Boeshaar, Patricia 252.15 Boettcher, Markus 212.03, 212.05D, 408.02 Bogard, Arthur 346.13 Bogdanov, Slavko 234.01, 234.05 Bogdanović, Tamara 432.15 Boggs, Stephen 254.25 Bohlen, Elizabeth 116.08 254.04, 254.23 Bohlin, Ralph Bohlin, Ralph C. 254.02, 254.12 Bois, Maxime 422.04 Boischot, Andre 146.08 Bolatto, Alberto 132.04D, 147.02, 417.04 Bolatto, Alberto D. 255.08 Bolduc-Duval, Julie 158.08, 420.02 Boley, Aaron C. 343.15 Bolin, David E. 411.03D Bolte, Michael 153.11 Bomans, Dominik J. 245.01 239.03 Bonati, Marco Bond, Howard 153.10 Bond, Howard E. 105.03, 251.16, 337.18 Bond, J. Richard 109.03D Bond, Nicholas 407.01 Bonfield, David 430.24 Bongard, S. 308.01 Bongard, Sebastien 308.04 Bongard, S 337.13 Bonnatto, Charles 310.01 Bonnell, Jerry T. 142.49 310.06, 408.01 Bonning, Erin W. Bono, Giuseppe 434.19 Bonomo, Aldo 418.08 Bonsor, Amy 419.01D Bontemps, S 340.13 Bontorno, Anna 342.18 Bookbinder, Jay 425.03 Boom, Charla 410.05 Bootes Survey Collaboration, 106.05 Boquien, Mederic 250.03

Border, James 156.01 Borders, Tiffany 254.39 Borders, Tiffany M. 251.16, 254.37 Borguet, Benoit 432.02, 432.03 Borkin, Michelle A. 258.13 Borkowski, K. 256.13 Borkowski, K. J. 256.12 Borkowski, Kazimierz J. 256.21, 256.22 Borland, Brittin 152.13 Borne, Kirk D. 252.04, 252.09 Boroson, Todd A. 142.22 148.03 Borsch, Noah Borucki, William J. 103.04 Borucki, W. J. 103.07 Bosch, James 252.23, 403.02D Bosh, Amanda S. 306.05 Boslough, Mark B. 156.08 Boss, Alan 253.10, 340.12 Boss, Alan P. 429.09 Bostroem, K A. 254.02 Bostroem, K. A. 254.04 Bothwell, Matthew 229.03D Bottorff, Mark 346.03 Botzer, Brandon 253.09, 401.01, 401.02 Boucarut, Ray 254.16 Bouchez, Antonin H. 340.04 Boulanger, Francois 335.27 Bouret, Jean-Claude C. 144.19 Bouret, J C. 154.08 Bourjaily, Matthew 142.04 Bourke, Tyler 258.16 Bourke, Tyler L. 340.09, 340.31, 340.35 Bournaud, Frederic 422.04 Boutan, Christian 150.03 Bouvier, Jerome 340.22 Bouwens, Rychard 115.05, 229.06 Bouwens, Rychard J. 229.05 Bouzid, Samia 338.10 Bovill. Mia S. 424.02D Bovy, Jo 222.05, 222.06 430.37 Bowen, David Bower, Geoff 240.06 Bower, Geoff C. 240.01 Bower, Geoffrey C. 240.02 Bower, Geoff C. 240.03 Bower, Geoffrey C. 240.07

Bowers, Chuck 254.08 Bowers, Sharon 248.08 Bowman, Judd 107.09 Bowman, William C. 418.01, 418.02 Bowsher, Emily 434.15 Bowsher, Emily C. 434.14 Boyajian, Tabetha 140.18, 343.07 Boyajian, Tabetha S. 242.03, 242.23, 415.04 Boyd, Mark R. 242.05, 242.26 Boyer, Martha L. 154.04 Boylan-Kolchin, Michael 147.03 Boyle, Richard P. 340.11 Bozek, Brandon 147.06 Braatz, Jim 142.57 Braatz, James A. 245.09, 408.06D Bradford, Matt 244.02 Bradley, Richard 107.09 Bradley, Rich 432.06 Bradstreet, David 140.15 Bradstreet, David H. 144.07 Brafford, Suellen 257.09 Braglia, Filiberto 109.05 Brainerd, Tereasa G. 403.01 Brammer, Gabriel 335.23 Bramson, Ali 149.26 Branch, David 337.17 Brand, Peter W. J.. L.. 251.23 Brandt, John C. 129.02 Brandt, W. N. 142.53 Brandt, W N. 142.54 Brandt, W. N. 230.01, 230.02, 252.17 Brassfield, Erin 340.09 Brault, Michelle 149.30 Braxton, Kelsey 256.06 Brazier, Adam 234.01, 234.05 Brecher, Kenneth 129.03 109.05 Bregman, Joel Bregman, Joel N. 152.17, 417.05 Breiner, Jonathan 220.07 Brennan, Drew 248.10, 342.03 Brenneman, Laura 142.21, 142.42 Brenner, Douglas 344.18, 413.05D Bressert, Eli 145.03 Brewer, Brendon 430.18 Bridge, Carrie 333.13, 333.14, 333.17 Briggs, Michael S. 434.01

Bright, Len 306.05 141.01 Brinchmann, J. Brinkworth, Carolyn 420.03, 420.04 Brissenden, Gina 247.01, 247.05, 247.08, 247.09, 252.04 Britt, Christopher B. T. 418.02 Britt, Christopher T. 144.24 Brittain, S. 340.19, 340.29 Brittain, Sean 434.21, 434.47 Brittain, Sean D. 145.10 Broadhurst, Tom 109.05 Brodie, Jean P. 312.02D 249.09 Brodwin, M. Brodwin, Mark 308.05D Brogan, Crystal 256.14, 434.32 Brook, Chris 409.01 Brooke, Timothy 334.09 Brooke, Timothy Y. 334.10 Brooks, Alyson 335.44 Brooks, Aidan F. 432.23 Brooks, Alyson M. 246.16 Brooks, Keira 430.16 Broos, Pat 144.26 Broos, Patrick S. 409.05 Brothers, Timothy C. 306.05 Brotherton, Michael S. 142.03, 142.04, 142.05 Broughton, Peter 111.02 Brown, Anthony G. A. 153.01 Brown, A. 154.06 Brown, Alexander 154.07, 339.13 Brown, A. 340.19, 340.29 Brown, Alexander 340.33, 340.34 Brown, Andrew R. H. 241.03 Brown, Benjamin 242.22 Brown, Benjamin P. 155.12 Brown, Edward F. 308.02, 324.06D, 337.01, 432.12 Brown, J. 340.19 Brown, Justin 341.04 Brown, J. M. 340.29 Brown. Joanna M. 340.34 Brown, M. 242.06 Brown, Michael E. 252.10, 306.04 Brown, P. 308.01 Brown, Shanique 158.14 Brown, Steven W. 157.15, 348.03 Brown, Tim 103.03 Brown, Tom 152.12

Brown, T. M. 103.07 Brown, Warren 341.04 Brown, Warren R. 423.02 Browning, Matthew K. 242.21, 242.22 Bruce, Amanda 258.05 Bruce, John 251.11 Bruderer, Simon 258.05 Brugamyer, E. 103.07 Brun, Allan S. 242.22 Brun, Sacha 155.12 Brunner, Robert J. 222.06 252.09, 252.17 Brunner, R. J. Bruno, Oscar 253.07 Brunthaler, A. 323.06 Brusa, Marcella 335.37 Brusentsova, Tatyana 202.01 Bryant, Mark A. 345.10 Bryden, Geoffrey 140.20, 157.12 Bryden, Goeffrey 339.08 Bryson, Steve 140.01, 140.05 Bryson, Steve T. 140.04 Bryson, Stephen T. 140.07 344.12 Bu, YingYi 103.04 Buchhave, Lars A. Buchhave, Lars C. A. 201.02 Buckley-Geer, Elizabeth 239.04, 347.01, 347.02 Buckley-Geer, E 347.03 Buckley-Geer, Elizabeth J. 239.03 Budavari, Tamas 156.05 Budiardja, Reuben 337.23, **410.02D** Buffington, Andy 257.02 Bugno, Jessica L. 144.11, 342.09 Bui, Khanh 157.11 Buil, Christian 257.04 Buitrago, Fernando 430.22 Bullock, Eric 126.06 Bullock, James 207.02, 207.03 Bullock, J. 252.14 Bullock, James S. 147.03 Bundy, Kevin 335.40 Bunker, Andy 254.27 Buote, David 116.04 Burdon, Crosby 435.01 Bureau, Martin 312.04, 335.08, 422.02D, 422.04 Burgaser, Adam J. 434.10 Burgasser, Adam 252.15, 434.14

Burgasser, Adam J. 226.05D, 242.02, 242.04, 242.19, **343.14**, 434.11, 434.15 Burgh, Eric B. 251.20 Burke, Bernard F. 429.09 Burke, Christopher 343.11 Burke, Christopher J. 220.06 Burkhart, Blakesley 241.03, 251.02 Burns, Jack O. 107.09, 149.14 Burrows, Adam 253.10, 402.05, 402.08, 418.03 Burrows, David 425.02 Burrows, David N. 141.07, 256.28 Burse, Mahesh 157.11 Burton, Michael G. 113.04, 251.23 Bus, Schelte 257.09 Buscher, David 157.09 Busha, Michael 213.06, 249.07, 249.08, 433.16 Bushouse, Howard 254.36, 254.37, 254.39, 254.41 Bushouse, H. 323.06 Bushouse, Howard A. 254.38 Bustamante, Sandra 258.26 Butler, Bryan J. 413.01 Butler, Nat 157.07 Butler, Paul 153.02 Butner, Harold M. 255.01 Butner, Melissa 250.02 Buton, C. 308.01 Buton, Clement 308.04 Buton, C 337.13 Butterfield, Natalie 335.04 Buxton, Michelle 408.01 Buxton, M M. 143.04 Byler, Eleanor 142.27 Byrd, Matthew 149.03 Byun, Do Y. 430.21 Byun, Yong-Ik 116.01 C-BASS Collaboration, 334.07 Caballero-Nieves, Saida M. 152.32 Cabanela, Juan E. 241.10 204.02 Cabre, Anna Cabrera, Guillermo 344.13 Cackett, Edward M. 432.12 Cadigan, Jessie 248.06 Cady, Eric 253.05, 254.29 Cai, Kai 429.02 Calder, Alan C. 308.02, 324.06D, 337.01 Caldwell, Caroline 142.65 Caldwell, Douglas 140.05

Caldwell, Doug 201.02 Caldwell, Nelson 153.16 Cales, Sabrina 142.05 Callegari, Simone 421.07D 255.15, 322.03D Calvet, Nuria Calzetti, Daniela 112.03, 202.07, 245.03, 246.04 Camero-Arranz, Ascension 434.01 Cami, Jan 158.08 Camilo, Fernando 139.05, 234.01, 234.05 Campo, Christopher J. 402.02, 418.02 Canadian Advanced Network For Astronomical Researc, h 344.04 Canadian Astronomy Data Centre, 344.03 CANDELS. 211.04 Cannizzo, John K. 201.09 308.01 Canto, A. Canto, Arnaud 308.04 Canto, A 337.13 Cantrell, Andrew 432.14 Cantrell, Andrew G. 144.20 Canzian, Blaise 157.17 Capak, Peter 128.06, 334.09, 334.10 Capak, Peter L. 430.23 Capellupo, Daniel M. 142.30 Cappellari, Michele 148.08, 312.04, 335.08, 422.02D, 422.04 Carciofi, Alex C. 339.22, 339.24 Cardall, Christian 337.23, 410.02D Cardamone, Carolin N. 233.04, 326.01, 335.23 Cardoso, Rogerio Fernando 336.05 Carey, S 340.13 Cargile, Phillip 252.15 Cargile, Phillip A. 153.05 Carilli, Chris 107.09, 335.21, 430.11, 430.23, 432.06 Carini, Michael T. 140.17 Carlberg, Joleen K. 158.05, 307.04D Carlin, Jeffrey L. 334.13 Carlotti, Alexis 254.30, 254.31, 254.32 Carlton, Ashley 256.12 245.13 CARMA team, Carney, Bruce W. 152.11, 311.02D Carney, Mason T. 338.03 Carollo, Marcella 229.05 Carona, Don 433.09 Carpenter, John M. 302.04, 419.03, 419.04 Carpenter, K. G. 154.06 Carpenter, Kenneth G. 154.07 Carr, J 157.03

Carroll, Nicole 434.52 Carroll, Patricia A. 150.03 Carroll, Sean 257.03 Carter, Joshua A. 201.01, 343.03 Caruso, Sally 248.13, 340.08 Case, Gary L. 434.01 425.05 Casement, Suzanne L. Casertano, Stefano 335.01 Cash, Jennifer 140.11, 342.11, 342.12, 342.13 Cash, Jennifer L. 145.10 Cash, Webster C. 433.01 Cassata, Paolo 335.03, 430.35 Cassell, Dustin 249.01 Castelaz, Michael 256.26, 334.01 Castelaz, Michael W. 346.14 Castro, Daniel 130.02D 432.20 Catanzarite, Joseph Catanzerite, Joe 425.01 Catelan, M. 252.14 Catelan, Márcio 252.15, 311.03D Catelan, M 334.17 Catling, David 113.07 Caton, Daniel 116.06 Cawthon, Ross 251.12 Cease, H. 239.04 Ceballos, Frank 336.12 Cecil, Gerald 211.02D Cederbloom, Steven E. 142.53 Cenko, S. B. 108.02D Center for Astronomy & Physics Education Research, (CAPER) Team 405.03, 405.04, 405.05 130.01 Cerrigone, Luciano Cesaroni, R. 255.03 Ceverino, Daniel 211.04 Chaboyer, Brian 152.13, 152.14 Chaboyer, Brian C. 242.25 Chakrabarti, Supriya 250.09 Chakrabarti, Sukanya 421.02 Chakraborty, Nachiketa 337.28 Challis. Peter 246.10.337.32 Chamberlain, Heather 144.06 Chamberlin, Phillip C. 319.02 Chambers, Edward 258.22 Chambers, Edward T. 323.07 Chambers, Kenneth C. 222.02 Champion, David J. 234.01 Chamulak, David 308.02

Chamulak, David A. 324.06D Chan, B.H.P. 344.08 Chan, S. J. 250.12 152.06 Chandar, R. Chandar, Rupali 152.07, 246.12, 246.17 Chandler, Claire J. 413.01 Chang, Chihway 252.07, 252.08, 252.18, 252.21, 252.25 Chang, Philip 421.02 Chaplin, Vandiver 434.01 Chapman, Nicholas L. 112.07 Chapman, Scott 229.03D Chapman, Scott C. 310.06, 430.28 Charbonneau, David 220.04, 343.11, 349.04, 402.08 Charles, Proffitt 254.28 Charlot, S. 141.01 Charlot, Stephane 254.27 Charlton, Jane 152.07, 345.04, 345.05, 345.07 Charlton, Jane C. 142.04, 335.07 Charmandaris, Vassilis 333.06 Chartas, G. 252.17 Chartrand, Alex M. 142.53 Chary, Ranga-Ram 231.06 ChASeM33 Team, 246.10 Chatterjee, Ritaban 408.01 Chatterjee, Shami 234.01 Chatterjee, Shamibrata 234.05 Chatterjee, Shami 256.15 434.28 Chatzopoulos, Emmanouil Chaubell, Julian 253.07 Chayer, Pierre 338.15 Che, Xiao 257.03 Chen, Chin-Wei 312.03 Chen, C.H. R. 258.28 Chen, Hsiao-Wen 108.02D, 309.03D, 412.04D Chen, Jianjun 334.13 Chen, Ying-Tung 435.02 339.20 Cheng, Kwang-Ping Cherry, Michael L. 434.01 Chesley, Steven R. 252.10 Chesny, David 155.10, 155.11 Cheung, Chi C. 106.03D Cheung, C. C. 108.06, 336.07 Cheung, Chui L. 256.03 Chevalier, Roger 337.24 Chiang, Hsin-Fang 340.17 Chiba, M 157.03

Chiba, Tamara 310.06 Chiboucas, Kristin 147.07 Chies Santos, Ana 312.02D Chilcote, Jeffrey K. 339.04 308.01 Childress, M. Childress, Michael 308.04 Chin, Rachel M. 433.14 Chincarini, Guido 108.04 230.04 Chini, Rolf Chiu, Bella C. 210.05 Chiw, Charisee 152.33 Cho, James Y. K.. 302.07 Choi, Ami 335.32 Choi, Jieun 155.01 Choi, Jun-Hwan 309.04, 335.05, 345.01, 421.05 Choi, Philip I. 433.14 Choi, Yumi 142.63 Chojnowski, Drew 142.07, 434.50 Chojnowski, Stephen D. 142.08 Cholis, Ilias 432.10 Chomiuk, Laura 256.33, 258.29 Chopra, Nitish 251.07 Chordia, Pravin 157.11 Chornock, R. 337.21 Chornock, Ryan 337.26 Chotard, N. 308.01 Chotard, Nicolas 308.04 Chotard, N 337.13 Christensen, Charlotte 216.02D, 328.05 Christensen, E 334.17 Christensen, Finn 254.25 Christensen, Justin 248.10 Christian, Carol 344.07 Christian, Carol A. 251.16, 252.04 Christiansen, Jessie 103.01, 201.02 Christiansen, Jessie L. 220.04 Christlieb, Norbert 242.12 432.08 Christopherson, Adam Chrysostomou, Antonio C. 251.23 Chu, Jason 335.41 Chu, You-Hua 147.01 Chu, YouHua 147.02 Chu, You-Hua 152.30, 256.29, 258.28, 339.14 Chubak, Carly 434.12 Chun, Mark 114.01 Chun, M 157.03

Chun, Mark 253.10, 258.33 109.02D Churazov, Eugene Church, Candace M. 423.04D Church, Sarah 433.10 Churcher, Laura 419.02D Churchill, Christopher W. 412.05 Churchwell, Ed 241.14, 241.16 Chuss, David 313.05 Ciardi, David 140.05, 220.03, 242.03 Ciardi, David R. 140.20, 220.05, 242.23, 415.04 Ciardullo, Robin 421.04 Cieza, Lucas A. 339.09, 340.10 Cikota, Aleksandar 112.01, 324.02 Cinabro, David 252.20 Ciolek, Glenn E. 251.01, 251.03 Ciotti, Luca 212.04 Cisler, Andrew 337.04 Civano, Francesca 125.04D, 142.42, 142.56, 430.23 Civano, Francesca M. 335.37 Claire, Mark 113.07, 156.02 Clampin, Mark 254.08, 302.02, 402.08 Clark, Barry 146.05 Clark, Barry C. 413.01 Clarke, Bruce 140.05 Clarke, Fraser 148.08, 253.10 Clarke, John T. 156.08 Clarke, Tracy 413.03 Clarkson, Andrew 157.17 Clarkson, Will 241.12, 303.04 CLASH Team, 227.06 Claussen, Mark 154.05, 434.46 Claussen, Mark J. 338.16 Claver, Chuck 334.11 Claver, Chuck F. 252.02 Clavier, David 346.14 Clayton, Geoffrey 337.22 Clayton, Geoff 341.06, 341.07 Clayton, Jessica 139.08, 336.12 Clegg, Andrew W. 344.10 Clem, James 337.22 Clem, James L. 144.24, 338.14 Clemens, Dan 112.07 Clemens, Dan P. 241.15, 250.05, 251.03, 251.04 Clementini, Gisella 342.17 Clements, Christopher 248.06 Clements, David L. 430.29

Clerc, Nicolas 149.19 Cline, J. Donald 346.14 Cline, J. D. 334.01 Close, Laird M. 253.10 Clover, John 257.02 Clowe, Douglas 252.23 Cluver, Michelle 335.27 Cochran, Jeffrey M. 258.08 Cochran, William 201.02 Cochran, W. D. 103.07 Cochran, William D. 343.06 Cody, Ann Marie 113.03D Coe, Dan 227.06, 430.37 Coe, Dan A. 109.05 Cohen, Aaron 413.02 Cohen, Leah 155.10, 155.11 Cohen, Martin 113.07, 130.01 Cohen, M. 333.08, 333.09 Cohen, Martin 333.10 Cohen, Ofer 429.05 Cohen, Seth 335.19 Cohen, Seth H. 142.40, 335.18 Cohn, Haldan N. 241.13 Cohn, Joanne D. 204.06 Coil, Alison L. 229.01D, 325.04 Colavita, M. M. 429.09 Colbert, James 333.06, 407.08 Coldwell, Georgina 335.29 Collaboration of Astronomy Teaching Scholars (CATS,) 247.01, 247.02, 247.03, 247.05, 247.06, 247.07, 247.08, 247.09 Collier-Cameron, Andrew 402.02, 418.02 Colombo, Dario 246.11 Colucci, Janet E. 328.04D Comastri, Andrea 335.37 Condon, Jim 142.57 Condon, James J. 408.06D 308.07 Conley, Alex Conley, Alexander 337.11 Connaughton, Valerie 434.01 Connelley, Michael S. 340.01 252.08, 252.18, 252.21, 252.25, 344.09, 344.12 Connolly, Andrew Connolly, Andrew J. 142.63, 151.06, 153.04, 156.05, 252.07 252.24 Connolly, A. J. Connolly, Brian 335.31, 337.02, 337.07 Connolly, Natalia 150.05 Connolly, N. 249.09

Connolly, N 249.10 Connolly, Natalia 308.05D, 337.02, 337.07 Connor, Thomas 430.30 Conroy, Kyle E. 152.18 Conroy, Peter 253.02 Conselice, Christopher J. 430.22 Consiglio, Jennifer 207.03 Constantin, Anca 106.06, 125.07 145.01, 250.02, 344.07 Conti, Alberto Contreras, Daniel S. 433.14 Contursi, Alessandra 202.08 Converse, Joseph M. 427.03D Conwill, Laura 344.11 Cook, Kem 252.15 433.09 Cook, Kyle Cook, Timothy A. 250.09 Cooke. Jeff 412.05, 423.01 Cool, Adrienne M. 152.16, 434.18 Cool, Richard J. 229.01D Cooper, Andrew L. 335.34, 335.35 Cooray, Asantha 231.06, 249.02, 249.03, 249.04, 255.09, 255.10, 255.13 Cooray, Asantha R. 255.11 Copin, Y. 308.01 Copin, Yannick 308.04 Copin, Y 337.13 Coppi, Paolo 106.04, 126.04 Coppi, P. 252.17 Coppi, Paolo 408.01, 433.18 Corbally, Christopher J. 242.08 Corbett, Stephanie 149.10 Corby, Joanna 158.05 Corcoran, Michael 144.26, 338.17 Cordes, James 139.04, 234.01 Cordes, Jim 234.05 Cordes, K. 158.06 Cordiner, Martin 112.04 Corman, Adrian 349.05 Cormier, Sebastien 247.05 Corradi. Romano 256.02 Corrales, Lia 250.10 Corwin, Jr., H.G. 344.08 COSMOS Collaboration, 335.37 COSMOS Team, 125.04D 430.27 COSMOS/zCOSMOS group, Costa, Dan 248.06 Cote, Miles 140.01

Côté, Patrick 312.03 Cotera, Angela S. 113.04 Cottam, Stella 146.07 Cotten, David L. 434.37 Cotter, Garret 142.01, 142.02 Coughenour, Blake 413.06 Coughlin, Jeffrey 201.04, 257.05 Coughlin, Jared 343.04 Covarrubias, Ricardo A. 434.25 Covey, Kevin 153.07, 252.15, 343.02 Covey, Kevin R. 153.05, 153.06, 340.32, 401.03D Covino, Stevano 108.04 Cowan, Nicolas B. 343.13, 402.07 Cowley, Charles R. 113.05 254.40 Cox, Colin Cox, Erin 155.08 Cox, Nick L. J.. 112.04 Cox, Pierre 430.11, 430.23, 430.28 Cox, T.J. 424.04D Cox, Thomas J. 310.04 Cozens, Glen 146.03 Crabtree, Dennis 157.19, 158.08, 420.02 Craig, Helen A. 336.02 Craig, Joe 413.03 Craig, William 254.25 Cramer, Claire 348.03 Cramer, Claire E. 157.15 Crane, Jeff 413.07 Crawford, Fronefield 215.01 Crawford, Fronfield 234.01 Crawford, Fronefield 234.05 Creech-Eakman, Michelle 157.09 Creighton, Jean 139.08, 336.12 Crenshaw, D. M. 142.12, 142.14 Crenshaw, Daniel M. 142.15 Crenshaw, Mike 142.13 344.18, 413.05D Crepp, Justin Crepp, Justin R. 302.05 Crews, Caroline 337.35 Crisp, David 349.04 Crocker, Alison F. 112.03 Crockett, Christopher 253.13, 253.14 Crockett, C 343.01 Crockett, Mark 312.04 Croft, Steve 240.02 Croll, Bryce 418.08

Crone-Odekon, Mary 149.29 Crook, Aidan 150.02 Crossfield, Ian J. M.. 302.07 Croston, J. H. 125.05 Crovisier, Jacques 156.03 Croxall, Kevin V. 255.08 Crump, Rachel 248.13, 340.08 Cruz, Kelle 242.04, 242.17, 434.10, 434.11 Cruz, Kelle L. 145.03, 226.05D, 307.01 Csak, Balazs 253.02 Csubry, Zoltan 253.01, 253.02 Cuesta, Antonio 222.07 Cuesta-Vazquez, Antonio Jose 150.05 Cuillandre, Jean-Charles 207.02, 207.03, 207.04D Culliton, Christopher C. 252.13 Culverhouse, Thomas 323.01 Cunha. Carlos 433.16 Cunha, Katia 242.01 Cunningham, Maria 113.04 Cunnyngham, Ian 114.01, 258.33 Cuntz, Manfred 415.05 Currie, Thayne M. 418.03 Curtin, Leanne 345.08 242.06 Curtis, B. Curtis, Jason L. 152.29 Cushing, Michael 253.10, 333.03, 418.08 Cushing, Michael C. 343.14, 430.12, 434.10 Cutri, Roc 333.07, 333.18, 333.19 Cutri, Roc M. 158.09, 430.19 CWI Team, 426.04 258.23 Cyganowski, Claudia 109.05 Cypriano, Eduardo Czakon, Nicole G. 413.04D D'Abrusco, Raffaele 433.22 D'Antona, Francesca 152.15 D'Avanzo, Paolo 108.04 346.04 D'Cruz, Noella L. D'Elia, Valerio 108.04 D'Ercole, Annibale 152.15 D'Onghia, Elena 417.06 430.40 D'Orazio, Daniel J. da Costa, Luiz A. N. 150.05, 249.06 da Costa, Luiz N. 430.04 Daddi, Emanuele 335.21 Dahlen, Tomas 254.39, 334.05 Dahm, Scott E. 339.12

Dalcanton, Julianne 147.08, 147.09, 147.10, 207.02, 207.03, 222.01, 328.01 Dalcanton, J. J. 152.19 Dalcanton, Julianne J. 233.05, 434.25 417.08 Dale, Daniel 255.08 Dale, Daniel A. Dalessio, James 341.05, 432.22 Damjanov, Ivana 211.01D Damke, Guillermo 337.32 Danforth, Charles 345.11 Danforth, Charles W. 142.36, 217.06, 345.08, 345.12 Daniel, Jay 157.17 Daniel, Scott 151.05, 153.04 Danner, Rolf 145.04, 425.05 Dannerbauer, Helmut 335.21 250.09 Danowski, Meredith E. DAOof TAU Team, 340.34 Daou. Doris 431.07 Dark Energy Survey, 239.04 Dark Energy Survey Collaboration, 239.01 Darling, Jeremy 258.03, 345.02 Darling, Jeremiah K. 335.10 Darragh, Andrew N. 152.18 Dartez, Louis 336.12 Das, Hillol 157.11 Das, Sudeep 313.02 Daus, Catherine S. 158.14 Dave', Romeel 309.02D 242.13 Davenport, James R. Davenport, James R. A. 242.20, 341.01 David, Laurence 142.18 David, Reitzel B. 241.12 Davidson, James 339.24 Davidson, Kris 154.12 Davidson, Jr., James W. 339.21 Davies, James 105.03 Davies, Jonathan I. 149.23 Davies, Randy 248.01 Davies, Richard I. 142.46, 430.28 Davies, Roger L. 148.08, 422.04 Davis, Andrew J. 116.03D Davis, Ben 246.09 Davis, David S. 125.02 Davis, Timothy 422.02D 422.04 Davis, Tim Davis, Timothy A. 335.08 Davy, Claire M. 430.04

Dawson, Kyle 157.10 Dawson, K. 249.09 Dawson, K 249.10 Dawson, Kyle S. 308.05D Dawson, Rebekah 156.10 Day, David 139.08, 336.12 Day, Peter K. 413.04D De, Soma 434.24 de Gouveia Dal Pino, Elisabethe 253.10 de Grijs, Richard 152.09 de Jong, Roelof 417.01 De Lee, Nathan 334.12 De Lee, Nathan M. 242.29 De Marchi, Guido 254.27, 258.27 De Marco, Orsola 105.03, 144.18 De Mello, Duilia F. 327.04, 335.20 de Messieres, Genevieve 158.05 De Pasquale, Massimiliano 108.04 de Pater, Imke 156.08, 240.03 De Propris, Roberto 149.02, 149.17, 241.12 de Simoni, Fernando 150.05 de Swardt, Bonita 207.06 De Vries, Christopher H. 258.12 de Vries, W. 252.17 de Zeeuw, Tim 422.04 Dearholdt, Will 156.09 Deb, Sanghamitra 227.01, 227.02 252.14 Debattista, V. Debattista, Victor 417.01 Debattista, Victor P. 241.11 Debes, John H. 333.08 333.09 Debes, J. H. Debois-Felsmann, Gregory P. 252.02 DeBoth, David 155.10, 155.11 **DEBRIS** Survey Team, 255.01 DeCoster, Rich 248.10 342.03 DeCoster, Richard 433.05 Deen, Casey Degenaar, Nathalie 432.12 DeGeorge, Martin 342.02 DeGioia-Eastwood, Kathleen 144.26 Deharveng, Jean-Michel 426.04 Dekaney, Richard 413.05D Dekany, Richard 157.11 Dekany, Richard G. 340.04 Dekel, Avishai 211.04, 309.06

del Hoyo, Javier 254.16 DeLaney, Tracey 256.15, 256.16 Delannoy, Jean 146.08 DeLee, Nathan 311.03D DeLeo, Gary G. 144.05 Deleuil, Magali 418.08 Delgado, Francisco 252.02 Deliyannis, Constantine P. 152.38 Dell'Antonio, Ian P. **252.23**, 335.32 Della Corte, Dennis 157.10 Dellenbusch, Kate 245.07 Dembicky, Jack 257.05 Deming, Drake 220.04, 302.07, 349.04, 402.02, 402.08, 418.01, 418.02 Demorest, Paul B. 139.05, 139.06, 234.01 Demory, Brice-Olivier 103.08 Den Hartog, Elizabeth A. 349.06 Dencheva, Nadezhda 344.15 Deneva, Julia 234.01, 336.09 Deneva, Julia S. 234.05 Deng, Licai 152.09, 334.13 Dent, William 202.05 DePonte Evans, Janet 413.07 DePoy, D. L. 433.09 433.12 DePoy, D. L. Derome, Laurent 252.19 DeRoo, Cailah 343.01 Derylo, G. 239.04 DES Collaboration, 433.16 Desai, Shantanu 334.03 Desch, Steven J. 340.06 Desert, Jean-Michel 103.09, 402.08 Desjardins, Tyler D. 144.23 Destree, Joshua P. 251.20 Desvignes, Gregory 234.01, 234.05, 240.04 Dettmar, Ralf-Juergen 245.01 Deustua, S. 249.09 Deustua, Susana 254.41, 324.02 Deustua, Susana E. 112.01, 250.02, 254.12, 420.01 Devereux, Nicholas A. 326.04 Devinney, Edward J. 342.02 Devlin, Mark J. 227.05D Devriendt, Julien 424.03D DeVries, Joe 252.05 deVries, Wim H. 430.16 Dewahl, Kathleen 157.18 Dewarf, Laurence 343.12

Dewey, Daniel 256.16, 256.28, 434.26, 434.31 Dexter, Jason 303.01D Dexter, Matt 240.06 Dey, A. 249.09 Dhawan, Vivek 156.01, 413.01 Dhital, Saurav 145.03, 252.15, 307.03, 334.12 Di Francesco, James 158.08, 241.02, 420.02 Di Milia, Giovanni 116.08 Di Stefano, Rosanne 318.03, 347.06 Diaferio, Antonaldo 109.01 Diamond-Stanic, Aleksandar M. 230.01, 230.02 Dickel, John R. 256.29 Dicken, Daniel 430.14 Dicker, Simon 227.05D Dickinson, Mark 128.03D, 255.12 Dickman, Robert L. 413.01 Diddams, Scott 253.09, 401.01, 401.02 Dieball, Andrea 144.24 Diehl, H. Thomas 239.02 Diehl, H.T 347.03 Diehl, H. T. 239.04, 347.01, 347.02 Diehl, Roland 434.01 Diehl, Steven 144.18, 341.07 Dieterich, Sergio B. 242.05 Dietrich, Matthias 430.07 DIGIT Team, 202.04 Dijkstra, Catharinus 250.15 Dilday, Benjamin 252.20 DiMilia, Giovanni 145.01 Dinerstein, Harriet L. 145.02, 256.04 DIXI Observing Team, 306.07 DIXI Team, 306.06, 306.08 Dixon, Morgan 251.12 Dixon, Van 145.04 Dixon, W. Van 254.01 Dixon, William V. 254.12, 338.15 Djorgovski, George 156.08, 433.22 Djorgovski, S. G. 252.09 Djorgovski, Stanislav G. **310.07**, 334.02 Djorgovski, S G. 334.17 Djorgovski, S. G. 344.11 Do, Tuan 241.18, 303.04 Dobler, Gregory 432.10 Dodds-Eden, K. 323.06 Dodson-Robinson, Sarah 340.26 Doeleman, Sheperd S. 143.01

Doering, Mark 248.13, 340.08 Doering, Ryan L. 258.07 Dogan, Mehmet 241.17 Doi, M. 249.09 Doi, M 249.10 Doi, Mamoru 308.05D Dolag, Klaus 125.06 Dolch, Timothy 231.06 233.05 Dolphin, A. Domagal-Goldman, Shawn 220.07 Domagal-Goldman, Shawn D. 343.09 Donahue, Megan 148.07, 227.06 Donahue, M. 249.09 Donaldson, Jessica 202.05 344.07 Donaldson, Thomas Donalek, Ciro 334.02 Donalek. C 334.17 Donalek, Ciro 344.11 Donehew, Brian 434.47 Dong, Feng 430.39 Dong, Ruobing 149.13 Donley, Jennifer 431.01 Donoso, Emilio 432.01 435.03 Doose, Lyn Dopita, Michael 114.05D Dopita, Michael A. 245.03 Dorman, Claire 207.03 Dorman, Claire E. 207.02 Dormody, Michael 434.05 Dorsey, William 146.02 Dossett, Jason 432.05 Dotson, Jessie 140.01, 140.05, 313.05 Dotter, Aaron 152.12, 152.20, 152.21, 152.23 Dotter, A. 152.24 Dotter, Aaron 152.25, 152.26, 152.27 Dotter, Aaron L. 152.22 258.05 Doty, Sandy Doty, Steven 258.05, 258.06, 258.08, 339.06 Doty, Sarah 346.03 Doty, Steven D. 258.09 241.01, 241.02, 241.06 Douglas, Kevin Douglas, Kevin A. 241.03, 241.04, 251.29 Douglas, Stephanie 242.09 Doull, Brandon 337.03 Dowell, D. 323.06 Dowell, Jayce 413.03

Dowell, Jayce D. 417.03 Downes, Thomas P. 413.04D Downing, S.W. 149.25 Doyle, Laurance R. 140.04, 140.12 Dragomir, Diana 429.08 Draine, Bruce T. 202.07 Drake, Andrew 344.11 Drake, Andrew J. 334.02, **334.17** Drake, Jeremy J. 429.05 Drake, Stephen A. 154.01 Draper, Zachary H. 339.22 Droettboom, Michael 344.15 Drory, Niv 325.01D, 407.09 Drosback, Meredith 158.05 Drosback, Meredith M. 258.14 Drout, Maria 153.16 Drumheller. Dean 257.08, 346.09 Duan, Ran 413.04D Dubois, Richard 144.27 Duerbeck, Hilmar 146.11, 146.12 Duffau, Sonia 241.17 Duffin, Dennis 434.36 Dugan, Chuck 248.03 Dulude, Michael 254.38, 254.39, 254.40, 254.41 Dumas, Gaelle 246.11 Dumke, Michael 216.06 Dumont, Philip 253.12 Dumoulin, Robert 432.13 Duncan, Douglas 247.04 DUNES Team, 255.02 Dunham, Edward 140.05 Dunham, Edward W. 306.05 Dunham, Miranda K. 411.03D Dunham, Michael M. 340.31 Dunlop, James S. 335.51 Dunn, Jay 432.02, 432.03 Dupke, Renato 109.05, 149.27 Dupke, Renato A. 423.03 DuPre, Katherine 306.05 Dupree, Andrea 103.03 226.01, 253.10 Dupuy, Trent Duran, Maria 152.37 Durech, Josef 252.10 Durisen, Richard 429.02 Durisen, Richard H. 343.15 Durrell, Patrick 152.07

Durrell, Patrick R. 152.03 Durret, Florence 149.21 Dusenbery, Paul B. 158.01 Dussault, Mary E. 431.05 Dutil, Yvan 158.08 Dutton, Aaron A. 309.06 Dvorak, Shawn 338.14 Dwarkadas, Vikram 251.13, 434.26 Dwarkadas, Vikram V. 256.28 Dwek, Eli 229.04 340.03 Dwyer, Sara Dzib, Sergio A. 434.46 Eagan, Will 337.02 Eastman, Jason 220.02D Eastwood, Kathy 242.07 Ebel, Denton 202.01 Eberle, Jason 415.05 Ebert, Monica 155.10, 155.11 Ebert, R. 344.08 Eckert, Kathleen D. 334.14, 334.15 Edelstein, Jerry 401.03D Edgar, Clyde E. 433.13 Edge, Alastair 430.38 Edmonds, Doug 432.02, 432.03 Edwards, Louise 158.08 Edwards, Louise O. 127.02 Edwards, Louise O. V. 149.21 Edwards, Michelle 156.08 Edwards, M L. 152.05 Edwards, Michelle L. 338.18 323.06 Edwards, P. Edwards, Zachary 256.30 Egami, Eichi 255.14 Egami, Eiichi 430.32 Egami, Eichi 430.37 Egami, Eiichi 430.38 Eggen, Joseph 142.24 EHT Collaboration, 143.01 Eikenberry, Stephen S. 338.18, 433.07 Eimer, Joseph 313.05 Eiroa, Carlos 255.02 Eisenhamer, Bonnie 158.06 Eisenhardt, P. 249.09 Eisenhardt, Peter 308.05D, 333.11, 333.14, 333.19 Eisenhardt, Peter R. 158.09 Eisenstein, Daniel J. 229.01D

Eisner, J. A. 340.07 Eisner, Josh A. 340.25 Eissner, Werner B. 434.40 Eiting, Jacob 239.03 Elbaz, David 255.12 Elitzur, Moshe 142.50, 430.20 Ellinger, Carola I. 423.05 249.09 Ellingson, E. Ellingson, Steve 413.03 Elliot, Ann 239.03 Elliot, James L. 306.05 Ellis, Justin 139.03 Ellis, Jennifer 433.24 Ellis, Richard 335.40 Ellis, Richard S. 423.01 Ellman, Nancy 241.17, 433.18 Ellsworth-Bowers, Timothy 411.03D Ellsworth-Bowers, Timothy P. 340.20 Elmegreen, Bruce 147.14, 258.01 Elmegreen, Debra M. 207.05 Elvis, Martin 125.04D, 142.21, 142.42, 142.56, 335.37, 430.23, 433.22 Emery, Joshua P. 340.01 Emonts, Bjorn 115.04 Emsellem, Eric 142.46, 335.08, 422.02D, 422.04 Endeve, Eirik 337.23, 410.02D Endl, Michael 201.02, 343.06 Engel, Tyler 251.28 Engel, Tyler D. 251.30 Engelbracht, Charles W. 417.08 Engelhardt, Sabrina 338.12, 338.13 Engle, Scott 144.01, 144.02 Engle, Scott G. 144.04, 342.06, 343.12 Enoch, Melissa 411.06 Enriquez, J. Emilio 337.21 Enya, K 157.03 EPoS, 202.03 EPOXI Earthling Team, 349.04 Epps, Harland 413.07 Eracleous, Michael 142.04 Eracleous, M. 252.17 Eracleous, Michael 421.04 Eracleous, M C. 142.54 Erb, Dawn 139.08 Ercolano, Barabara 337.22 Erickcek, Adrienne L. 403.06 Erskine, David J. 401.03D

Erwin, Peter 421.01 Espaillat, Catherine 131.03, 322.03D Espinoza, Pablo 339.01 339.03 Esposito, Thomas **ESSENCE** Project, 403.04 Estevao, Thales G. M.. 423.03 Esteves, David A. 256.05 Estrada, Juan 239.04 Etxaluze Azkonaga, Mireya 323.05 Evans, Aaron 115.04 Evans, Christopher J. 112.04 Evans, Daniel A. 106.04 Evans, Ian 413.07 Evans, Jessica M. 152.30 Evans, Nicole 343.09 Evans, Neal J. 202.04, 411.03D, 434.43 Evans, Nancy R. 144.26, 434.19 Evans II, Neal J. 340.31 Even, Wesley 341.06, 341.07 Everett, John 245.04 Everett, John E. 241.19 EVLA Scientific Commissioning Team, 157.02, 338.16 Evrard, August 213.06 Fabbiano, Giuseppina 433.22 Fabbri, Joanna 337.22 Fabbro, Sebastien 344.04 Faber, S.M. 422.05 Faber, Sandra M. 211.04 Fabian, Andy 335.39 Fabian, A. C. 149.15 Fabregat, Juan 339.24 Fabrycky, Daniel 201.01, 220.04, 418.03 Fabrycky, Daniel C. 103.05, 140.13 Faccioli, L. 249.09 Faccioli, Lorenzo 308.05D Fadda, Dario 127.02, 149.21 Fadely, Ross 147.17, 245.12, 424.01 Fadeyev, V. 249.09 Fadeyev, V 249.10 Fadeyev, Vitaliy 308.05D Faesi, Christopher 340.32 Faherty, Jacqueline 226.05D, 434.11 Faherty, Jacqueline K. 242.02, 434.10 Fahlman, Greg 152.20, 152.21, 152.22, 152.23 Fahlman, G. 152.24 Fahlman, Greg 152.25, 152.26, 152.27

Fajardo-Acosta, Sergio 333.05, **333.06** Fakhouri, H. 249.09 Fakhouri, H 249.10 Fakhouri, H. 308.01 Fakhouri, Hannah 308.04, 308.05D, **337.13** Falck, Bridget 204.05D Falco, Emilio 343.11 Falco, Emilio E. 348.03 Falcon, Ross E. 433.24 Falcone, Abe 425.02 Fallscheer, Cassandra L. 416.03D Fan, Xiaohui 142.40, 230.01, 230.02 Fan, X. 252.17 Fan, Xiaohui 430.11, 430.37 Fanelli, Michael 140.01, 140.02, 201.06 Fanelli, Michael N. 140.08 Fang, Julia 306.01 Fang, Kelvin 334.02 Farah, Alex 157.07 Fardal, Mark A. 207.01 Farr, Will 415.07 Farrah, Duncan 335.51 Farrell, Sean 432.17, 432.25 Farrell, W. M. 343.25 Farrington, Chris 242.03, 257.03, 415.04 Fassnacht, Christopher D. 225.01, 252.22, 430.01, 430.12 Fassnacht, Chris D. 430.25 Faulkner, Danny 144.06 Faulkner, Danny R. 144.14 Fay, Jonathan 420.04 Fazio, Giovanni 230.04 Fazio, GG. 340.13 Fazio, Giovanni G. 434.19 Feddersen, Jesse 147.16 Federman, Steven R. 256.23 Fedotov, Konstantin 152.07 Fegley, Jr., Bruce 402.01 Fehrmann, Henning 234.01 Feiden, Greg 140.18, 242.25 Feig, Michael 340.08, 346.07 Fekel, Francis C. 429.09 Feldman, Daniel 242.17 Feldman, Paul D. 254.10, 254.12 Feldmeier, John J. 149.25 Felli, Derek 245.10 Ferdman, Robert D. 139.05, 139.06

254.14 Ferguson, Brian A. Ferguson, Henry C. 231.06 Ferland, Gary 154.12, 233.03D Fermi Collaboration, 434.05 Fermi LAT collaboration, 105.06, 106.03D, 144.27 Fermi Science Suport Center, 254.35 Fermi Science Support Center, 254.33, 254.34 Fernandez, Rodrigo 410.04 Fernandez, Yanga R. 252.10 Ferrara, Elizabeth C. 254.33, 336.07 Ferrarese, Laura 312.03 Ferruit, Pierre 254.27 Fesen, Robert 130.05, 337.19 Fesen, Robert A. 256.19, 337.33 Fetherolf, Tara 201.03 Feuillet, Diane 152.13 Fich. Michel 411.05 Field, Tom 431.04 Fields, Brian D. 147.01, **231.01**, 337.28 Fienberg, Richard T. 248.03 Fierroz, David F. 142.60 Figer, Don 252.15 Figer, Donald F. 241.07, 335.48 Figueiredo, Pedro 202.01 Figueroa-Feliciano, Enectali 256.16, 434.31 Figura, Charles C. 411.04 Filippenko, Alex 324.04 Filippenko, Alexei V. 310.08, 324.05, 337.21, 337.26 Filippenko, Alex V. 337.32 Filippenko, Alexei V. 434.30 Finch, Charlie T. 242.05 Finger, Mark H. 434.01 Finkbeiner, Douglas P. 434.42 Finkelman, Ido 148.03 Finkelstein, Keely 149.19 Finkelstein, Keely D. 255.14 Finkelstein, Steven 149.19, 407.03 Finkelstein, Steven L. 255.14, 335.43, 407.09 Finley, Hayley 337.32 Finn, Rose A. 149.12 Finn, S. 255.03 Finzell, Thomas 144.17 Fiore, Fabrizio 108.04 FIREBALL Team, 426.04 Fischer, Debra 220.03, 343.03, 415.06 Fischer, Jacqueline 202.08

Fischer, Travis C. 142.12, 142.14, 142.15 Fischer, Will 255.15 Fischer, Will J. 255.04 Fish, Vincent 346.10 Fish, Vincent L. 143.01, 248.06 Fitzgerald, Michael P. 302.02, 339.03, 339.04 Fitzpatrick, Edward L. 242.28 313.05 Fixsen, Dale Fixsen, Dale J. 254.18 Flaherty, Kevin M. 434.45 FLAMINGOS-2 Early Science Survey Teams, 433.07 239.04 Flaugher, Brenna Fleming, Brian 254.10 Fleming, Scott 242.29, 334.12 Fleming, Scott W. 226.04D Fletcher, Corinne 331.02 Fletcher, Leigh 156.08 Flores, Mauricio 336.12 Flores, R. 239.04 Floyd, David 310.02 Fogarty, Lisa 148.08 Folatelli, Gaston 126.04 Foley, Ryan J. 337.10, **337.12** Foley, R. J. 337.21 Foley, Ryan J. 337.32 Folkner, William 156.01 Follette, Katherine B. 434.51 Fomalont, Edward 156.01 For, BiQing 153.08 Force, Megan 336.10 Ford, Anthony 336.12 Ford, Eric B. 103.05, 103.06, 140.09, 140.13, 343.18, 343.20 Ford, Holland 227.06 Ford, Holland C. 226.03 Foreman, Gary 149.04 Forestell, Amy D. 247.09 Forman, William 127.01D, 142.18, 335.26 125.05 Forman, W. R. Forrest, William J. 343.14 Fortney, Jonathan 418.01, 418.07 Fortney, Jonathan J. 402.04, 418.08, 429.03 Fortson, Lucy 106.04, 408.05 Fossati, Giovanni 212.02D, 408.01 Foster, Griffin 240.06 Foster, Jonathan 250.04 Foster, J. 255.03

Fox, Derek 425.02 Fox, Ori D. **142.49**, 157.07, 337.24 Foyle, Kelly 246.14 France, Kevin 245.02, 254.03, 258.11, 339.13, 339.18, 340.33, 345.11 Frank, Adam 256.02 Frank, Juhan 126.03 Frank, Kari A. 149.15 Frank, Stephan 426.04 Franx, Marijn 233.06, 254.27 Fraquelli, Dorothy A. 140.06 Fraser, Gerald T. 157.15 Fraser, Wesley 306.04 Frate, Meghan 142.24 Frattare, Lisa M. 251.16 Frayer, C. 344.08 Frayer, David 334.09 Frayer, David T. 127.02, 202.09, 245.08 Frazer, Chris 249.03 Frebel, Anna 147.04, 242.12, 413.07 Freedman, Richard S. 402.04 Freedman, Wendy 311.04 Freire, Paulo 234.05 Freire, Paulo C. C.. 139.05 Freire, Paulo C. C. 234.01 French, Linda M. 111.04 French, Rica S. 247.09 Frew, David 337.36 Frewen, Shane 343.19 Friberg, Sarah 147.11 Friberg, S. 147.12 Fricke, Kyle 158.02, 158.09 Fridriksson, Joel K. 432.12 Friedman, Robert B. 431.02 Friedman, Samuel H. 109.02D Friel, Eileen D. 152.39 Frieman, Joshua 347.01 Frieman, J 347.03 Friesen, Rachel 331.03 Frinchaboy, Peter 152.31 Frinchaboy, Peter M. 434.50 Frisch, Priscilla C. 434.34 Fritz, Alexander 335.15 Froelich, Kathy 209.05 Froning, Cynthia 434.04 Fruchter, A. 141.01, 249.09 Fruchter, A 249.10

Fruchter, Andrew S. 308.05D, 344.15 Fry, Alexander B. 150.03 Frye, Brenda 109.05 430.37 Frye, Brenda L. 341.06, 341.07 Fryer, Chris Fryer, Christopher L. 144.18 Fryer, Chris L. 423.05 Ftaclas, Christ 253.10 Fu, Hai 310.07 Fuchs, Joshua 245.05 Fuhrmann, Lars 142.01, 142.02 Fujiwara, H 157.03 Fujiyoshi, T 157.03 Fukagawa, Misato 339.05, 418.03 Fukuhara, Masayuki 246.04 Fukui, Yasuo 258.28 Fulbright, Jon P. 153.12 Fuller, Lindsay 432.09 Fumagalli, Michele 211.04 Funes, S.J., Jose G. 148.03 Funsten, Herb 434.34 Furesz, Gabor 413.07 Furlan, Elise 255.15, 339.19 Furlanetto, Stephen 107.09 Furgan, Muhammad 252.13 241.12 Fux, Roger Gabor, Jared 309.02D Gadotti, Dimitri 207.06 Gaensicke, Boris T. 126.06 Gaensler, Bryan M. 142.32, 240.01, 256.14, 256.27 Gaetz, Terrance J. 246.10, 256.22 Gagne, Justin 142.12 Gagne, Marc 144.26 Gaier, Todd C. 433.10 Gainge, Keith 142.02 Gair, Jonathan R. 432.21 Gaither, Bryan W. 254.12 Gal, Roy 114.03 Gal, Roy R. 430.25 Gal-Yam, Avishay 434.30 Galaxy Zoo team, 142.08 GALEX Team, 149.09 Gallagher, John S. 245.07 Gallagher, Joseph S. 337.22 Gallagher, Sarah 152.07 Gallagher, Sarah C. 142.03, 335.07

Gallagher III, John S. 245.04 Gallagher, III, J. S. 433.13 Gallazzi, Anna 335.34 Gallo, Elena 148.05 Galvan-Madrid, Roberto 416.02D Gamble, Lee 248.13, 340.08 Ganeshalingam, Mohan 324.04, 324.05 Ganeshalingam, M. 337.21 Ganeshalingam, Mohan 337.26 Gangler, E. 308.01 Gangler, Emmanuel 308.04 337.13 Gangler, E Ganguly, Rajib 142.03, 142.04, 142.05 Garaud, Pascale 307.06, 311.01 Garcia, Alejandro 336.12 Garcia, Eugenio 432.18 Garcia, Karen 156.12 Garcia, Michael R. 144.25, **425.03** Garcia, Sarah 434.10 Garcia-Burillo, Santiago 246.11 Gardner, Jeff 344.12 Gardner, Jonathan P. 254.12, 335.19 Garmany, Catherine 337.18 Garmany, Catharine D. 145.05 Garnavich, Peter 338.10 Garnavich, Peter M. 337.10 Garner, Sarah 248.09 Garnett, Donald R. 342.16 Garraffo, Cecilia 429.05 Garrell, T. 257.04 Garrett, Michael 106.04 Garrod, Robin T. 251.19 Gartner, Constance 248.13, 340.08 Gaudi, Scott 242.29, 334.12 Gauthier, Jean-Rene 412.04D Gautier, Thomas N. 103.03, 140.05 233.04, 252.19, 407.01, 407.04, 407.09 Gawiser, Eric Gawiser, Eric J. 335.23, 407.02 Gawronski, M. P. 142.53 Gay, Pamela 106.04, 344.01 Gay, Pamela L. 158.13, 158.14, 247.05, 344.02 Gayley, Kenneth G. 154.09, 319.04 Gaztanaga, Enrique 204.02 Ge, Jian 226.04D, 242.29, 334.12 Geary, John 413.07 Geballe, Tom 341.06

Geballe, Thomas R. 251.23 Geballe, T. R. 256.04 Gebhardt, Karl 151.02, 325.01D, 403.03D, 407.09, **422.05**, 422.06 Gee, Perry 335.32 424.03D Geen, Sam Geha, Marla 207.04D, 424.01 Geha, Marla C. 252.14 Gehrels, Neil 108.03, 157.07, 326.02D, 434.01 Geiss, Brian B. 241.13 Gelderman, Richard 209.01 Gelfand, Joseph 256.14, 434.07 Gelino, Christopher 333.03 Gelino, Dawn 220.03 Gelino, Dawn M. 429.04 Geller, Aaron 144.17 Geller, Aaron M. 152.31, 152.34, 327.02 109.01 Geller, Margaret J. Gemini Planet Imager team, 339.04 GEMS Team, 254.42 Gentile, Gianfranco 246.23 Genzel, Reinhard 128.04, 202.08 323.06 Genzel, R. Genzel, Reinhard 430.28 Georganopoulos, Markos 212.02D, 212.06 Gerdes, David 213.06, 337.04 Gerdes, David W. 150.04 Gerhartz, Cody 149.31 Gersch, Alan 435.05 Gershun, Daniel 249.12 Gettel, Sara 253.04 Ghavamian, Parviz 254.01, 256.21, 256.22 Ghavmian, Parviz 254.02 Ghent, Chrysta 346.02 Ghez, Andrea 241.18 Ghez, Andrea M. 303.04, 411.02 242.01 Ghezzi, Luan 142.62, 245.10, 434.33 Ghosh, Tapasi GHOSTS Collaboration, 417.01 Giavalisco. Mauro 335.03, 430.35 Gibb, Erika 434.21 Gibb, Erika L. 131.02D Gibbs, Michael 209.04 Gibson, Brad 409.01 Gibson, Robert 142.03 Gibson, Rob 252.08 Gibson, Robert 252.17, 252.21

Gibson, Rob 344.09 Gibson, Robert 430.16 Gibson, R R. 142.54 Gibson, Robert R. 142.63, 252.07, 252.18, 252.25 Gibson, Steven 241.01 Gibson, Steve 241.02 Gibson, Steven J. 241.03, 241.04, 241.06, 251.29 Gies, Douglas R. 152.32, 154.11, 242.07, 339.23, 406.03 Gil de Paz, Armando 417.02D Gilbank, D. 249.09 Gilbank, David 424.01 Gilbert, Karoline 207.02, 207.03, 207.04D Gilbert, K. 233.05 Gilbert, Karoline 328.01 Gilbreth, Blaine N. 433.14 Gilker, Justin 334.08 Gillessen, S. 323.06 Gilliland, Ron 103.03, 140.05, 254.36, 254.37 Gilliland, Ronald 402.08 Gilliland, Ronald L. 103.04 Gilliland, R. L. 103.07 Gilmore, D. K. 252.06 Gilmore, Gerard 152.28 Gilmore, Gerard F. 147.06 Gilmore, Kirk 252.07, 252.08, 252.18, 252.21, 252.25 Gilmore, Rudy 231.02 Gilpin, Claire 215.01 Ginsburg, Adam 258.02, 258.03, 411.03D Giovanelli, Riccardo 115.03, 334.14 Giri, Suman 139.01 Gladders, Michael 114.04 Gladders, M. 249.09 Gladders, Michael 308.05D, 424.01 Gladders, Michael D. 213.02D, 227.04D Gladman, Brett 306.03 Glass, Ian 146.09, 146.11 Glass, Lisa 312.03 Glass, Margaret 209.06 Glasse, Alistair C. H.. 433.06 Glassman, Tiffany 253.07 145.04 GLBTQastro, Glenn, Jason 244.02, 413.04D Glikman, Eilat 142.50 GLIMPSE360 team, 241.14, 241.16 Glover, Simon C. O.. 216.01 Gnedin, Nickolay Y. 335.24

GNS Team, 430.22 Go, Christopher 156.08 Goderya, Shaukat 433.21 432.25 Godet, Olivier Godon, Patrick 338.04, 338.05 Goldberg, David M. 227.01, 347.04 242.03 Goldfinger, PJ Goldfinger, P. J. 415.04 Goldhaber, G. 249.09 Goldhaber, G 249.10 Goldhaber, Gerson 308.05D 152.20, 152.24 Goldsbury, Ryan Goldsmith, Paul 112.07, 202.06 Goliasch, Jonas 338.01 Golimowski, David 254.14, 344.16 Golwala, Sunil R. 413.04D Gombosi, Tamas I. 429.05 Gomez, Gilberto 434.36 Gomez, Thomas 256.02, 256.09 Gomez, Tomas 338.14 Gomez, Thomas 342.17 Gonçalves, Thiago S. 325.03 Gondolo, Paolo 157.10 Gonzales-Gaitan, Santiago 308.07 Gonzalez, A. 249.09 Gonzalez, Anthony H. 430.12 Gonzalez, Jesus 157.07 Gonzalez, Marjorie E. 139.05, 139.06 Gonzalez, Marjore E. 234.01 Gonzalez, Valentino 229.06 González-Alfonso, Eduardo 202.08 Gonzalez-Alfonso, Eduardo 323.05 Goobar, A 249.10 Goobar, Ariel 308.05D, 434.27 Goober, A. 249.09 Goodman, Alyssa A. 217.01, 258.13, 420.05 GOODS-Herschel team, 255.12 GOODS-NICMOS Collaboration, 335.22 152.09 Goodwin, Simon P. Gordon, Karl 112.01, 258.24, 258.28, 324.02 Gordon, Karl D. 250.09, 251.27, 254.23 Gorecki, Alexia 252.19 Gorelick, Noel 343.22 Gorjian, Varoujan 142.38, 142.43, 248.11, 248.12, 310.08 Gorodenski, S. 257.04 Gorski, Mark 258.30

Gosnell, Natalie 144.17 Gosnell, Natalie M. 152.31 Goss, Miller 105.05, 258.29 Gossen, Lauren 144.24 Gostisha, Martin 251.08 Gostisha, M. C. 251.07 Gostisha, Martin C. 251.28, 251.30 Gou, Lijun 404.02, 432.14 Gould, Roy 431.05 Goulliard, Renaud 425.01 Governato, Fabio 128.01D, 147.09, 216.02D, 246.16, 328.05 Graber, Emily L. 142.09 Grace, Emily 252.07, 252.08, 252.18, 252.21, 252.25 Graciá-Carpio, Javier 202.08 Grady, Carol 339.05 Grady, C. A. 340.19 Grady, Carol 430.24 Grady, Carol A. 340.29 Graham, John 141.01 Graham, James 407.06 Graham, James R. 302.02, 318.04, 339.03, 339.04, 422.06 Graham, M. 252.09 Graham. Melissa 308.06 Graham, Matthew 344.11 Graham, Matthew J. 334.02 Graham, M J. 334.17 Grainge, Keith 142.01 Gralla, Megan B. 227.04D Grammer, Skyler 241.10 Grant, Carolyn S. 116.08 GRAPES team, 335.45 Grasha, Katie 345.02 Grav, Tommy 435.02 Gray, A. G. 252.17 Gray, Richard O. 242.08 Grcevich, Jana 241.01, 241.02, 241.03, 241.04, 241.06 Great NASA Observatories M82 Extended Survey Team, 325.07 427.05D Grebel, Eva 256.12, 256.13 Green. D. A. Green, James C. 245.02, 338.15, 345.12 Green, Jerica M. 256.06 Green, Paul 142.17, 149.10, 153.03, 425.03 Green, Paul J. 125.07, 310.04 Green, R. F. 252.17 Greenberg, Richard 343.22, 415.01 Greene, Jenny E. 142.11, 430.15

Greene, Thomas P. 254.06, 402.04, 433.05, 434.20 Greenhill, Lincoln 116.07, 430.09 Gregg, Trevor A. 201.03 Gregorio-Hetem, Jane 253.10 Greiner, Jochen 434.01 Greiss, Sandra 144.24 Gressler, William J. 252.05 Greve, Thomas R. 233.04, 430.28 Greyber, Howard D. 249.11 Grier, Catherine 430.07 146.09 Griese, John Griffeth, Alice 256.26 Griffin, R. E. 257.06 Griffith, Caitlin A. 435.03 333.03, 333.11, 333.15 Griffith, Roger Griffith, Roger L. 430.12 Grillmair, C. 252.14 Grimes, Caleb K. 256.33 Grindlay, Jonathan 201.07 Grindlay, Jonanthan 434.08 Grindlay, Jonathan E. 144.24 Groff, Tyler D. 254.30 Grogin, Norman 254.14, 344.16 Grogin, Norman A. 334.15, 335.01 Groh, Jose 338.17 Gronwall, Caryl 147.16, 245.15, 250.07, 421.04 Groom, Steve 333.18 Groom, Steven 344.05 Groot, Paul J. 144.24 Grosso, Monica 339.24 Grosso, Nicolas 340.30 Grove, J. E. 336.06, 336.07 Groves, Brent 417.08 Gruendl, Robert 147.01, 258.28, 339.14 Grunblatt, Samuel K. 432.16 Grundstrom, Erika 105.06, 248.04, 339.23 Grundstrom, Erica D. 406.03 Gu, Diane 431.06 Guainazzi, Matteo 142.13 Guaita, Lucia 407.02, 407.04 Gude, A. 249.09 Gudkova, Diana 142.24 Guedel, Manuel 105.05, 338.19 Guedes, Javiera 421.07D Gugliucci, Nicole 158.05, 432.06 Guha Niyogi, Suklima 250.15, 250.16
Guhathakurta, Puragra 207.02, 207.03, 207.04D Guillard, Pierre 115.04, 335.27 Guillen, Reynal 431.06 Guillou, Ludovic 156.07 Guinan, Edward 140.18, 342.06 Guinan, Edward F. 140.10, 342.02, 343.12 Gulbis, Amanda A. S. 306.05 Gull, George 157.04 Gull, Theodore R. 338.17 Gully-Santiago, Michael 433.05 Gultiken, Kayhan 422.05 430.39 Gunn, James Gunn, James E. 430.06 Guo, Yicheng **335.03**, 430.35 Gupta, Harshal 217.07 Gupta, Ravi 213.01 Gurton, Suzy 158.01 Gurton, Suzanne 209.06 Gurwell, Mark 212.01 Gurwell, Mark A. 142.23 Gustavson, Kathy 139.08 Gutermuth, Rob 258.16 Gutermuth, Robert 258.21 Gutermuth, Rob 340.32 Gutermuth, Robert A. **258.19**, 340.04 Gutermuth, R A. 340.13 Guvenen, Blythe 247.10 Guver, Tolga 215.05 Guy, Mark 209.05 Guyon, Olivier 254.06 Guzik, J. A. 103.07 Guzman, Dani 413.07 Gwyn, Stephen 116.05 Gyuk, Geza 431.02 H-ATLAS Consortium, 255.13 Haarsma, Deborah B. 149.08 230.04 Haas, Martin Haas, Michael R. 140.07 Haas, Roland 432.15 Haberl, Frank 256.28 Habib, Salman 127.04 Hack, Warren 344.15 Haddad, Chris 139.01 Hadjiyska, Elena I. 433.18 Hafez, Ihsan 146.01 Haffner, L. M. 251.04, 251.05, 251.06, 251.07, 251.08 Haffner, L M. 251.09 433.11 Hagen, Alex Hagen-Thorn, Vladimir A. 142.55 Haggard, Daryl 125.07, 142.17, 430.13 Haggerty, Colby 144.15 Hahn, Joseph M. 406.06 Hailey, Charles 254.25 Hailey-Dunsheath, Steve 202.08 Haiman, Zoltan 225.02, 326.07 Haines, Tim 335.34 Hainline, Kevin 430.15 Hakkila, J. 252.09 Hakkila, Jon 432.11 Hales, Christopher A. 142.32 Haley, Kate 209.06 Halford, Melissa 251.09 Hall, Donald N. 425.07 Hall, Shannon 157.16 Hall, T. 242.06 Haller, Gunther M. 433.02 HALOGAS Team, 246.19, 246.21, 246.22, 246.23 Halpern, Jules P. 142.30 Halpern, Mark 313.05 Hamaguchi, K. 340.19, 340.29 Hamaguchi, Kenji 340.30, 418.03 Hamann, Fred 142.30, 326.05 Hambly, Nigel C. 242.26 Hamden, Erika T. 241.03 Hamidouche, Murad 406.04 Hamilton, Andrew J. S.. 256.19, 335.24, 337.33 Hamilton, Catrina 340.02 Hamilton, Catrina M. 340.01 Hamilton, Forrest 251.16 Hamilton, Ryan T. 126.05 Hamilton, Timothy S. 335.25, 346.13 Hammel, Heidi 257.09 Hammel, Heidi B. 156.08 Hammer, David 234.01 Hammergren, Mark 431.02, 435.04 Hamper, Randall 346.05 Hamren, Kathryn 153.06 Hamren, Katie 153.07 Hamren, Katherine M. 401.03D Hamuy, Mario 434.25 Hancock, Paul 348.02 Handler, Gerald 338.14

Handlin, Daneil 337.16 Haney, Michael 239.03 Haniff, Chris 157.09 Hanish, Daniel 334.09 Hankins, Andrew 147.05 Hanlon, William 239.03 Hannel, Mark 252.07, 252.08, 252.18, 252.21, 252.25 Hansen, Brad 152.20, 152.21, 152.22, 152.23 Hansen, B. 152.24 Hansen, Brad 152.25, 152.26, 152.27 Hansen, Bradley M. 343.16, 343.19 Hansen, Brad M. S.. 302.07 Hanson, Margaret M. 152.01 Hao, Heng 125.04D Hao, Jiangang 213.06, 239.04 Haqq-Misra, Jacob 319.06D Hardcastle, M. J. 125.05 Hardegree-Ullman, Kevin 247.10, 258.26 Harding, Alice K. 215.04D Harding, P. 149.25 Hardy, Ryan A. 402.02, 418.01, 418.02 Harker, David E. 156.03, 306.06 Harker, Geraint 107.09 Harker-Lundberg, Brian 155.01 Harlow, George 202.01 Harmon, Robert O. 342.08 Harpe, Eric J. 126.06 Harper, Graham 340.33 Harper, G. M. 154.06 Harper, Graham M. 154.07, 339.13 Harper-Clark, Elizabeth 216.03D HARPS team, 429.08 Harrington, David 157.16 Harrington, Joseph 302.07 Harrington, Joseph 402.02 Harrington, Joseph 418.01, **418.02** Harrington, Patrick 105.03 Harris, Andy 202.09 Harris, Alan W. 252.10 Harris, Barbara G. 338.14 Harris, Hugh C. 156.06 Harris, Stewart E. 433.02 Harris, William 344.14 Harris, William E. 149.24 149.16, 344.13, 430.31 Harrison, Craig Harrison, Fiona 142.42, 254.25, 333.11

Harrison, Fiona A. 430.12 Harrison, Thomas 201.04 Harrison, Thomas E. 126.05, 152.40 Harrold, Samuel T. 339.06 Hart, Alexa H. 130.01 Hart, Michael 413.06 433.02 Hart, Philip A. Hartigan, Patrick 253.13, 253.14 Hartkopf, William I. 146.06, 429.09 Hartman, Jake 413.03 108.01D, 145.10, 251.25 Hartmann, Dieter H. Hartmann, Lee 255.15, 322.03D Hartung, Markus 253.10 Hartwick, F. D. A.. 337.11 Hartwick, Victoria 156.04 Hascall, Pat 252.02 Hashimoto, Jun 339.05 Hasling, Matthew W. 142.26 Hathi, Nimish 407.03 Hathi, Nimish P. 128.06, 142.40, 335.18, 335.19 Hattori, Takashi 308.05D Haubois, Xavier 339.22 Hauke, Engel 430.28 Hauschildt, Peter 434.24 Hawkins, Keith 242.14 Hawkins, Lindsay 258.26 Hawley, John F. 322.01 Hawley, Suzanne 242.24, 257.05 Hawley, Suzanne L. 242.13, 242.18, 242.20, 307.02D, 342.07 Hawley, Wendy 337.06, 341.09 Hayes-Gehrke, Melissa N. 247.03 Haynes, Martha P. 115.03, 334.14 Hayward, Suzanne G. 434.18 Hayward, Thomas L. 253.10 Hazelton, Bryna 150.03 HCG Collaboration, 312.05 246.20, 246.21, 246.22 Heald, George Heald, George H. 246.19, 246.23 Healey, Stephen E. 142.01 Healey, Steve E. 142.02 Healy, James 432.15 Heap, Sara R. 434.17 Hearty, Thomas 349.04 Heathcote, Bernard 339.24 Heatherly, Sue Ann 145.06, 209.08 Heaton, Jennifer 346.03

Hebb, Leslie 242.29, 402.02, 418.02, 432.18 Heckman, T. M. 114.07 Hedden, Abby 431.01 Heetderks, Henry D. 433.02 Heffner, Carolyn M. 201.03 Hegel, Paul 142.09 Heiderman, Amanda L. 434.43 Heiles, Carl 241.01, 241.02, 241.03, 241.04, 241.06, 245.11 Heiles, Carl E. 132.08, 251.29 Heilmann, Ralf K. 254.11 Heinke, C. 323.06 Heinz, Sebastian 109.02D Heiser, Arnold 432.18 Heitmann, Katrin 127.04 Heitsch, Fabian 258.28 Helder, Eveline A. 130.03D Hellier, Coel 402.02, 418.02 Helmboldt, Joseph F. 142.44 Helmboldt, Joe F. 229.02D Helou, George 335.27 Helou, G. 344.08 Hemenway, Mary Kay 158.02 Hendel, David 334.15 Hendel, David A. 334.14 Henden, Arne 126.06, 158.11, 158.12, 338.14, 340.27 Henden, Arne A. 252.04 Henderson, Chuck 157.04 Henkel, Christian 142.57, 216.06, 245.09 Hennawi, J. 249.09 Hennawi, Joseph 345.06 Hennawi, Joseph F. 213.02D, 222.05, 222.06 Hennebelle, Patrick 434.36 Henneken, Edwin A. 116.08 Henning, Jason W. 149.14 Henning, P. A. 246.18 Henning, T 202.03 Henning, Thomas 253.02, 255.15 Henning, Th. 340.19, 340.29 Henry, Gregory 220.03 Henry, Richard B. 256.07 Henry, Richard B. C.. 256.08 Henry, Todd 242.03, 415.04 Henry, Todd J. 242.05, 242.16, 242.26 HERACLES team, 133.04D, 246.14 217.07 Herbst, Eric Herbst, Hanna 149.07

Herbst, William 340.01, 340.02, 340.03 Herczeg, G. 340.19, 340.29 Herczeg, Gregory 340.34 Herczeg, Gregory J. 339.13 HerMES Consortium, 245.13, 255.09 HerMES Team, 255.05 Hernandez, Audra K. 216.04D Hernquist, Lars 417.06, 424.04D Herrmann, Kimberly A. 147.15, 158.04 Herrold, Ardis 248.03 Herschel ATLAS Team, 202.09 Herschel Lensing Survey, 430.38 Herschel Oxygen Project (HOP) Team, 202.06 255.10 Herschel-ATLAS Consortium, Herter, Terry 425.02 Herter, Terry L. 157.04, 340.04 Hertz, Edward 413.07 Herwig, Falk 144.18, 341.06 Hess, Kelley 127.05, 149.07, 149.31 Hess, Kelley M. 115.03 Hessels, Jason 234.05 Hessels, Jason W. T. 234.01 Hesser, James E. 158.08, 420.02 Hewagama, Tilak 349.04 Hewett, Paul C. 233.03D Hewitt, John W. 256.24 HEXOS Key Program, 217.07 Heyer, Mark 434.43 Heyl, Jeremy S. 152.26, 232.03, 234.02D Heymann, Frank 230.04 Hi-GAL Consortium, 258.02 Hi-GAL team, 202.02 Hibbard, John E. 335.07 Hibon, Pascale 335.43, 335.50 Hick, Paul P. 257.02 Hickox, Ryan C. 106.05 Hicks, Amalia 148.07 Hicks, Amalia K. 149.11 Hicks. Brian 413.03 Hicks, Erin K. 142.46 Hicks, Elizabeth P. 308.03 Hicks, Lee 334.08 Hicks, Michael 156.12 Hiebert-Crape, Bria 144.07 HIGGS Team, 255.06 Hilbert, Bryan 254.36, 254.38, 254.39, 254.41

Hilburn, Guy L. 142.51 Hileman, Edward 252.05 Hill, A. B. 108.06 Hill, Alex S. 251.06 Hill, A. S. 251.07 Hill, Gary 407.09 Hill, Gary J. 325.01D, 403.03D Hill, G. J. 433.12 Hill, Nicholas R. 154.02 Hill, Robert J. 254.12 Hillenbrand, Lynne 113.03D, 220.01, 344.18, 413.05D Hillwig, Todd C. 256.10, 256.11 Hillyer, Richard W. 246.02 242.24 Hilton, Eric Hilton, Eric J. 242.13, **307.02D** Hilton, Gene 313.05 254.19 Hilton, George M. Hinderks, James 313.05 Hindsley, Robert B. 144.16 Hindsley, R. B. 242.06 Hines, Dean C. 157.15, 433.06 Hinkel, Natalie R. 319.01 Hinkle, Kenneth H. 256.01 302.04, 344.18, 413.05D Hinkley, Sasha Hinojosa, Jesus 336.12 Hinshaw, Gary 313.05 Hintz, Eric G. **144.09**, 144.11, 144.12, 144.13, 157.13, 248.01, 342.15 Hinz, Joannah 417.08 **HIPPIES** Project, 128.05 Ho, Luis C. 246.05 Ho, Paul 434.44 Ho, Shirley 150.05, 222.06, 222.07 Hoadley, Keri 157.04 Hoadley, Keri L. 252.13 Hoard, D.W. 248.10, 257.09 Hoard, Donald W. 257.07, 257.08 Hoard, D. W. 333.08, 333.09, 334.10, 342.03 Hoard, Don W. 346.09 Hobbs, George B. 139.05 Hoch, David 253.07 Hoch, Zach 430.04 Hockey, Thomas A. 111.06 Hodapp, Klaus 339.05 Hodge, Jacqueline A. 347.04 Hodge, Paul 251.12 Hodges-Kluck, Edmund J. 106.02D

Hoeflich, Peter 337.33 Hoekstra, Henk 109.06 Hoekstra, H. 249.09 Hoekstra, Henk 308.06 Hoenig, Michael D. 335.15 Hoette, Vivian 340.08, 346.07 Hoette, Vivian L. 248.13 Hoffer, Aaron S. 148.07 Hoffman, Douglas 201.04, 430.19 Hoffman, Douglas I. 333.07 Hoffman, Jennifer 337.27 Hoffman, Kelsey L. 234.02D Hoffman, William 257.09 Hofmeister, Anne 112.05, 349.05 Hofmeister, Anne M. 112.06 Hogan, Brandon 230.07 Hogan, Kortney 158.13 Hogan, Mary C. 337.17 Hogerheijde, Michiel 340.35 Hogg, David 345.06 Hogg, David W. 222.05, 222.06, 229.01D Hogg, James 142.28 Hoi Ming Mok, Herwick 340.21 Hoidn, Oliver 433.14 Holberg, Jay 341.03 Holberg, Jay B. 341.02 Holbrook, Jarita 431.06 Holden, Brad 430.37 Holden, Bradford P. 233.06 Hole, K. T. 410.05 108.04 Holland, Stephen Hollister, Matthew I. 413.04D Holman, Matthew J. 103.05, 140.13, 201.01, 220.04 Holman, Matt J. 252.10 Holman, Matthew J. 343.03, 343.04, **435.02** Holmes, Justin 141.04, 141.06 Holtzman, Jon 242.24 Holtzman, Jon A. 153.09, 153.10, 342.16 Holwerda, Benne W. 433.17 Homan, Daniel C. 142.34, 310.03 Homan, Jeroen 432.12 Homeier, Derek 418.06 Honda, M 157.03 Hong, Jaesub 434.08 Hong, Sungryong 245.03 Honscheid, Klaus 239.03, 239.04

Hood, Carol E. 230.03D Hopkins, Jeff 257.01 Hopkins, J. 257.04 HOPS team, 255.04 Hopwood, Rosalind 255.13 Hora, Joe 130.01 Hora, Joseph 257.09 Hora, Joe 333.04 Hora, Joseph L. 258.07 Hora, J L. 340.13 Horn, Brandon 433.14 Hornbeck, J. 340.19 Hornbeck, Jeremy 340.29 Horner, Donald J. 254.34 Hornschemeier, Ann 245.15 Hornschemeier, Ann E. 335.07 Houghton, Ryan 148.08 House, Christopher 349.03 Hoversten, Erik 245.15 Hoversten, Erik A. 250.07 Howard, Andrew 220.03, 415.06 Howard, Christian 241.12 Howe, Bill 156.05, 344.12 Howell, Dale A. 308.07 Howell, D. A. 337.11 Howell, Dale A. 337.29, **337.31** Howell, Justin 344.05 Howell, Steve 140.11, 140.15, 248.10 Howell, Stephen 257.09 Howell, Steve 342.03, 342.12, 342.13 Howell, Steve B. 103.04, 126.01D, 126.05, 145.10, 201.09, 257.07, 257.08, 346.09 Howk, J. Christopher 345.09 Howley, Kirsten 207.04D Howley, Kirsten M. 207.02, 207.03 Hoyer, Sergio 126.04 Hristov, Viktor 249.02 Hrivnak, Bruce J. 342.10 Hsiao, E. 249.09 Hsiao, E 249.10 Hsiao, E. 308.01 Hsiao, Eric 308.04, 308.05D, 337.11 Hsiao, E 337.13 HST GO 12228 Team, 339.02 HST/NICMOS GC Paschen Alpha Team, 241.07 Hu, Kaiqi 241.19 Hu, Yi 152.09

Huang, K. 141.01 Huang, Wenjin 342.17 Huang, X. 249.09 Huang, X 249.10 Huang, Xiaosheng 308.05D Huard, Tracy 434.43 Huard, Tracy L. 340.10, 340.31 Hubeny, Ivan 152.12, 338.04, 338.05 Huber, Mark E. 337.32 Hubrig, Swetlana 113.05 Huchra, John 150.02 HUDF09 Team, 115.05, 229.05 Huehnerhoff, Joseph 257.05 Huelsman, Derek 434.19 Huerta, Marcos 145.03 Hueso, Ricardo 156.08 Huffenberger, Kevin 225.02, 313.04 Huffenberger, Kevin M. 244.01 Huggins, Patrick J. 256.03 Hughes, Annie 216.05, 246.11, 251.26 Hughes, Anna L. 322.02D Hughes, Gary B. 434.52 Hughes, Joanne D. 147.05 Hughes, John P. 256.14 Hughes, Philip A. 142.41 Huk, Leah N. 337.27 Hull, Anthony B. 157.15, 254.26 Hull, Tony 157.17 Humphrey, Philip 116.04 Humphreys, Roberta M. 154.12, 241.10 Hung, Li-wei 149.02, 149.17 Hunt, Leslie 417.08 Hunt, Stephanie 413.05D Hunt-Walker, Nicholas 242.24 Hunter, Deidre 147.13, 258.32, 328.03D Hunter, Deidre A. 147.14, 147.15 Hurlburt, Neal E. 155.07 Hurley, Jarrod 152.20, 152.21, 152.22, 152.23 Hurley, J. 152.24 Hurley, Jared 152.25 152.26, 152.27 Hurley, Jarrod Hurley, Jarrod R. 327.02 Hurley, Mairead 430.37 Hurst Schmitt, Anna 209.06 Hurt, Robert 158.09, 420.03 Hurt, Robert L. 420.04

Hutter, D. 242.06 Huynh, Minh 233.04 Hwang, Ho Seong 152.04 Hwang, U. 256.13 Hyde, Elaina A. 152.28 Hyland, David C. 343.10 Hynes, Robert I. 144.21, 144.24 Ianna, Philip A. 242.05 Ida, Shigeru 253.10, 415.06 Igna, Ciprian D. 311.06 Ignace, Richard 338.20 Ihara, Y 249.10 Ihara, Yutaka 308.05D Illingworth, Garth 229.06 Illingworth, Garth D. 229.05, 233.06 Illinois Cosmological Simulation Group, 213.03D Im, Myungshin 430.33 Imanishi, M 157.03 Impellizzeri, Caterina 142.57 Impellizzeri, Caterina V. M.. 408.06D Impellizzeri, Violette 331.02 Impey, Chris 158.13, 247.10 Impey, Chris D. 247.01, 430.08 in't Zand, Jean J. M.. 144.24 Inada, Naohisa 347.04 335.41 Inami, Hanae Indebetouw, Remy 241.16, 258.14, 258.20, 258.28 217.04D Indriolo, Nick Infante, Leopoldo 312.03 Ingleby, Laura D. 327.06 144.19 Iping, Rosina IRAM PdBI team, 245.13 Ireland, Michael 302.04, 343.07 Ireland, Michael J. 302.03 148.02, 149.27 Irwin, Jimmy Irwin, Jonathan 343.11 Irwin, Kent 313.05 Irwin, Mike 152.28, 434.48 Irwin. Phil 253.11 Isaacson, Howard 103.03 420.01 Isbell, Douglas Isella, Andrea 258.12, 419.03, 419.04 Ishak, Mustapha 432.05 Ishibashi, Kazunori 154.12 Isler, Jedidah 408.01 ISTOS Team, 426.04

Ita, Y 157.03 Itoh, Yoichi 418.03 Ivans, Inese I. 153.14, 346.06, 434.30 Ivezić, Željko 250.08 Ivezić, Željko 252.11 Ivezic, Zeljko 142.63, 212.07, 241.09, 241.11, 252.01, 252.10, 252.13, 252.15 Ivezic, Z. 252.17, 252.24 Ivezic, Zeljko 430.16 Ivison, Rob 202.09 Ivison, Rob J. 233.04 Ivison, Robert J. 430.28 Iye, Masanori 335.13 Izumiura, H 157.03 Jaacks, Jason 335.05 Jablonka, Pascale 213.05 Jackson, Aaron P. 308.02, 324.06D, 337.01 Jackson, Brian 402.06 Jackson, Bernard V. 257.02 Jackson, Floyd E. 325.07 Jackson, J. 255.03 Jackson, Laura 158.05 Jackson, Megan C. 328.03D Jacobs, Bradley 328.02D 147.07 Jacobs, Bradley A. Jacobs, Daniel 432.06 Jacobson, Heather R. 152.39 Jacobson, Robert 156.01 Jacobson, Seth A. 340.20 Jacoby, George H. 105.03 Jacoby, Suzanne 252.13 252.04 Jacoby, Suzanne H. Jaehnig, K. P. 251.07 Jaffe, Daniel 253.14 Jaffe, Daniel T. 253.13, 433.05 Jahoda, K 254.42 Jahoda, Keith 434.01 Jain, Bhuvnesh 151.06, 252.23 Jain, Kiran 155.04 Jake, Turner 435.03 Jakobsen, Peter 254.27 James, Bethan 337.18 James, C. R. 209.02 James, David 340.22 Jamil, Omar 212.03 Jang-Condell, Hannah 131.05 Jannuzi, B. 249.09

JANUS Team, 425.02 Janusz, Robert 340.11 Januszewski, William 251.16 Jao, Wei-Chun 242.05 Jarrett, Tom 150.02 Jarrett, Thomas 333.11, 333.12 Jarrett, Tom 333.15, 333.19 Jarrett, Thomas H. 335.27 Jarvis, Mike 151.06 Jarvis, Michael 252.23 Jaskot, Anne E. 256.07 Jayawardhana, Ray 226.01, 418.08 Jean, P. 108.06 Jedicke, Robert 252.10 249.09 Jee, J. M. Jee, M. James 252.23 252.24, 335.32 Jee, Myungkook J. Jeffery, Elizabeth 152.12 Jeffries, Mark 152.34 Jelinsky, Patrick 433.02 Jenet, Fredrick 139.03, 139.08, 234.05 Jenet, Frederick A. 234.01 Jenet, Fredrick A. 336.12 434.01 Jenke, Peter Jenkins, Jon 140.05, 201.02 Jenkins, Jon M. 103.02, 140.08 Jenks, Kevin 254.11 Jensen, Adam G. 343.06 Jensen, Eric 220.03 Jensen, Elizabeth 254.32 Jensen, Eric N. 242.16 Jensen-Clem, Rebecca 306.05 Jeon, Myoungwon 335.48 Jeon, Yiseul 430.33 Jernigan, G. 252.24 Jernigan, Garrett 252.25 Jernigan, J. Garrett 252.08 Jernigan, J. G. 213.01 Jernigan, J G. 252.07 Jernigan, J. G. 252.18 Jernigan, Jesse G. 252.21 Jetha, Nazirah N. 335.25 Jethava, Nikhil 313.05 Jha, Saurabh W. 337.10 Jhabvala, Christine 313.05 Ji, Jun 152.17

Jiang, Linhua 430.32 Jimenez-Serra, Izaskun M. 255.03 Jimenez-Teja, Yolanda 109.05 Jo, Young-soo 251.17 158.02, 335.22 Jogee, Shardha Johns-Krull, Christopher 253.14 Johns-Krull, C 343.01 Johns-Krull, Christopher M. 253.13, 340.01 Johnson, Andrew 251.25 Johnson, Adam 253.07 Johnson, Bradley 313.05 Johnson, Benjamin 417.08 Johnson, Benjamin D. 309.05 Johnson, B. D. 335.28 Johnson, Chelen 346.07 Johnson, Chelen H. 248.13, 340.08 Johnson, Christian I. 153.12, 241.12 Johnson, Daniel 434.02 Johnson, Elsa M. 434.29 Johnson, Jennifer 153.11 Johnson, John A. 302.05, 415.06, 418.08, 429.06 Johnson, Kelsey 158.05, 258.29, 335.04 Johnson, Kelsey E. 258.20, 335.07 Johnson, L. C. 152.19, 233.05 Johnson, L C. 309.05 Johnson, Lent C. 335.28 Johnson, Michael 256.30 343.05 Johnson, Marshall C. Johnson, Michael D. 256.29 Johnson, Ryan 127.01D Johnson, Traci 251.12 Johnson, Tyrel J. 215.04D Johnston, David 213.06 Johnston, Simon 105.06, 336.02 Johnstone, Doug 411.06 Joner, Lisa A. 342.09 Joner, Michael D. 144.09, 144.11, 144.12, 157.13, 310.08, 342.09, 342.15 Jones, Amy 340.26 Jones, Christine 127.01D, 142.18, 335.26 Jones, Courtney 427.02 Jones, Dayton 142.38 Jones, David 250.04 Jones, Dayton L. 156.01 Jones, Erica D. 144.21 Jones, Heather 248.01 Jones, Jeremy 343.07

Jones, Lynne 156.05, 252.07, 252.08, 252.11, 252.13, 252.18, 252.21, 252.25 **149.01**, 149.31, 349.02 Jones, Megan Jones, Mackenzie L. 241.13 Jones, Patricia B. 129.02 Jones, R. L. 252.10 Jones, Therese 345.07 Jones, Terry J. 157.18, 251.22 Jones, Tom W. 125.06 Jones-Forman, Christine 125.05 Jonker, Peter G. 144.24 Jordan, A. 252.14 Jordan, Andres 253.02 Jordán, Andrés 312.03 Jordan, Andres 413.07 Jordan, Estela 256.18 Jorgensen, Anders M. 242.06 Jorgensen, Jes 340.35 Jørgensen, Jes K. 340.31 Jorgenson, Kelsey 342.15 Jorgenson, Regina 412.02 Jorstad, Svetlana 212.01 Jorstad, Svetlana G. 142.37, 142.55, 408.04, 430.20 Joseph, Chuck 254.19 Joseph, Tana D. 409.03 Joshi, Manasvita 212.01 Joudaki, Shahab 249.04 Joung, M. R. 251.06 Joyce, Richard R. 256.01 Jozsa, Gyula 246.20, 246.22 Jozsa, Guyla I. G. 106.04 Juneau, Stephanie 128.03D Junkkarinen, Vesa 310.06 Jurgenson, Colby 157.09 Jurgenson, Colby A. 157.14 Juric, Mario 241.09 Juric, M. 252.14 433.19 Juric, Mario JWST Team, 254.05 Ka Wing, Leung 232.05 Kaaret, Philip 258.30 Kaasalainen, Mikko 252.10 Kacprzak, Glenn 412.05 Kaczmarek, Jane 127.05 Kaercher, Alyssa J. 142.09 Kahle, Duncan M. 254.12 Kahn, Steven K. 252.08

Kahn, Steven M. 213.01, 252.07, 252.18, 252.21, 252.25 Kaib, Nathan A. 252.10, 322.06 Kaiser, Mary Elizabeth 254.12 Kaiser, Mary E. 254.10 Kakkala, Mohanan 306.05 Kalas, Paul 302.02, 339.03 Kaleida, C. 152.06 Kaleida, Catherine C. 246.17, 327.01D Kalirai, Jason 152.20, 152.22, 152.23 Kalirai, J. 152.24 Kalirai, Jason 152.25, 152.26, 152.27, 207.02, 207.03 Kalirai, Jasonjot 207.04D Kalirai, J. 252.14 Kalirai, Jason 252.15, 254.37, 254.39 Kalirai, Jasonjot 254.41 Kalirai, Jason S. 152.21, 152.31 Kallivayalil, N. 252.14 Kallivayalil, Nitya 424.04D Kallman, Timothy R. 254.42 Kalogera, Vassiliki 105.04 Kaltenegger, Lisa 415.08 Kamp, I. 340.19, 340.29 Kanbur, Shashi 342.04, 342.18 Kane, Stephen R. 220.03, 220.05, 415.04, 429.04 Kane, Timothy J. 402.03 Kang, Ji-hyun 251.29, 256.25 Kang, Rick 248.02 Kangaslahti, Pekka P. 433.10 Kann, D. A. 108.01D Kannappan, Sheila 334.14 309.01D, 334.15, 335.46 Kannappan, Sheila J. Kantor, Jeff 252.03 Kao, Melodie 149.16 Kaplan, David 139.08 Kaplan, David L. 126.01D, **341.08** Kaplan, George H. 344.14 Karachentsev, Igor D. 147.07 Karakla, Diane 254.17 Karim. Alexander 335.12, 430.23 Karliner, Inga 239.03 Karliner, I. 239.04 Karnath, Nicole 340.18 Karr, Jennifer L. 340.14 Karr, Robin 139.08 Kasdin, Jeremy 254.29 Kasdin, N. Jeremy 253.05, 254.30, 318.02D

Kasdin, N. J. **253.12**, 254.31, 254.32 Kasen, Dan 308.07 Kasen, Daniel 337.26 Kasen, Dan 337.32 Kashikawa, Nobunari 308.05D, 335.13 Kashyap, Vinay L. 429.05 Kasian, Laura 234.01 Kasliwal, Mansi 157.11 Kasliwal, Mansi M. 222.04D Kaspi, Victoria 234.05 Kaspi, Victoria M. 234.01, 254.09 Kassim, Namir 413.03 Kasting, James F. 402.03 Kastner, Joel H. 340.30 Kataza, H 157.03 Katz, Maximilian 251.03 Katz. Neal 430.34 Kauffmann, Jens 416.01 Kautsch, Stefan J. 246.02 Kavelaars, JJ 306.02D Kaviraj, Sugata 106.04, 312.04 Kawada, Mitsunobu 249.03 Kawamura, Akiko 258.28 Kawamura, Jonathan 216.06 Kay, Laura E. 145.04 Kayal, Khalid 336.12 Kazin, Eyal 204.04D, 249.06 Kazlauskas, Algirdas 340.11 KCWI Team, 426.03, 426.04 Keating, Brian 249.02 Keel, William C. 106.04, 142.07, 142.08, 142.12, 142.40 Keenan, Ryan 231.04D Keeney, Brian 345.11 Keeney, Brian A. 345.12 Keil, Stephen L. 155.03 Keller, Luke 157.04 Keller, Lindsay P. 434.41 Kellermann, Kenneth I. 408.07 Kelley, Michael S. 156.03, 306.06, 306.07 Kellogg, Kendra 155.04 Kelly, Brandon C. 142.33, 430.08 Kelly, Douglas 433.05 Kelson, Daniel D. 233.06, 340.31 Kemball, Athol 337.28 Kemper, Francisca 114.06 Kempton, Eliza 418.06, 418.07

Kennea, Jamie 425.02 Kennedy, Rachel 155.02 Kennefick, Daniel 246.09 Kennefick, Julia 246.09 Kenney, Jeffrey D. P.. 115.01D Kennicutt, Rob 229.03D Kennicutt, Robert C. 202.07 Kent, Brian R. 149.22 Kenyon, Scott J. 423.02 Kepler, 140.16 Kepler Asteroseismic Science Consortium, 201.08 Kepler Science Team, 103.01, 103.02, 103.03, 103.04, 103.05, 103.06, 103.07, 103.08, 103.09, 140.02, 140.09, 140.13, 140.21, 201.01, 201.02, 201.06, 343.21 Kepley, Amanda A. 258.29 424.04D Keres, Dusan Kerschhaggl, M. 308.01 Kerschhaggl, Matthias 308.04 Kerschhaggl, M 337.13 Kerton, Charles R. 258.25 Kessler, Richard 252.20, 434.23 Keto, E 340.13 Keto, Eric 416.03D Ketzeback, William F. 257.05 Kewley, Lisa 114.05D Kewley, L. J. 141.01 Kewley, Lisa J. 335.41 Keyes, Tony 254.17 Khandrika, Harish G. 434.15 Kharb, Preeti 230.07 Khardon, Roni 116.01 434.04 Khargharia, Juthika Khochfar, Sadegh 422.04 Khostovan, Ali Ahmad 255.13 Khostovan, Ali A. 255.10 Khussainov, Dastan 343.10 Kilcoyne, A. L. D.. 256.05 Kilgard, R. E. 114.07 Kilgard, Roy E. 144.23, 325.07 Kilic, Mukremin 341.04, 423.02 Killingstad, Nina 248.13, 340.08 Kim, A 249.10 Kim, Dae-Won 116.01 Kim, Dong-Woo 125.07, 149.10 Kim, Eun-Kyung 433.08 Kim, Hwihyun 142.59 Kim, H. 152.06

Kim, Hwihyun 246.17 Kim, Hyerim 343.10 Kim, M.G. 249.03 Kim, Minjin 335.51 Kim, Michael 343.10 Kim, Minjoong 430.21 Kim, Phuong 430.10 Kim, Sam 255.10, 255.13 Kim, Serena 340.08 Kim, Sang Chul 430.10 Kim, Seong Jin 430.33 Kim, Sungsoo S. 335.48, 430.21 Kim, Taehyun 207.06, 207.08 Kim, Taeyhun 246.01 KIM, Young-Soo 433.08 Kimball, Amy E. 212.07 Kimble, Randy A. 254.05, 254.12 Kindratenko, Volodymyr V. 222.06 Kinemuchi, Karen 140.02, 140.03, 201.06 King, Ivan 152.20, 152.21, 152.22, 152.23 King, I. 152.24 King, Ivan 152.25, 152.26, 152.27 King, Jeremy 242.14 King, Jeremy R. 145.10, 242.01 King, Oliver 142.02 King, Oliver G. 142.01, 334.07 Kingery, Aaron 158.05 KINGFISH Team, 112.03, 202.07, 255.08, 417.08 Kippen, R. M. 434.01 Kipping, David M. 429.01 Kirby, Evan 430.02 Kirby, Evan N. 147.04 Kirk, Brian 140.10, 144.01, 144.02, 144.03 Kirk, Brian M. 144.04 Kirkpatrick, J. Davy 333.03 Kirkpatrick, J D. 242.04, 430.12 Kirshner, Robert P. 246.10, 324.01, 337.26, 337.32 Kislak, Michelle 334.11 Kiuchi, Furea 434.32 Kjeldsen, Hans 103.08 Klaus, Todd 140.01 Klein, Chris 157.07 Klein, C. R. 142.49 Klein, Richard I. 258.10 337.26 Kleiser, Io Klingenberg, Christian 251.06

Kloppenborg, Brian 158.11, 257.02, 257.09 Kloppenborg, Brian K. 158.12, 257.03 Kloster, Dylan 149.12 139.07 Kloumann, Isabel M. Knee, Lewis 241.02 Knevezic, Zoran 252.10 Kniazev, Alexei 148.03, 207.02 Knierman, Karen 431.01 Knispel, Benjamin 234.01, 234.05 Knoche, Richard A. 336.08 Knoll, Harrison 250.14 Knutson, Heather 402.08 Knutson, Heather A. 220.04 Ko, Jongwan 430.33 Kobulnicky, Chip 345.04 Kobulnicky, Henry A. 258.25 Kocevski, Dale 114.03 Kocevski, Dale D. 211.04, 430.25 152.28, 241.12 Koch, Andreas Koch, David 103.05 Koch, D. G. 103.07 Kochanek, Christopher 430.10 Kochanek, Christopher S. 347.04, 430.16 246.04 Koda, Jin Koekemoer, Anton 142.40, 335.03 Koekemoer, Anton M. 231.06, 335.18 Koenig, Xavier 333.04 Koester, Benjamin 213.06 Koester, B. 249.09 Koester, Benjamin 308.05D Koester, Benjamin P. 213.02D Koesterke, Lars 343.06 Kogan, Leonid 413.02 Kogut, Alan 244.03, 313.05 Koh, Haegon 340.14 Koh, Ju Heon 433.08 Kok, Yitping 140.18 Kollmeier, Juna 430.10 Kolobow, Craig 338.09 Konacki, Maciej 429.09 Kong, Jason 324.05 Kong, Jason J. 142.20 Konidaris, Nicholas 325.06 Konishi, Kohki 308.05D Konopacky, Quinn 302.01, 418.05 Konopacky, Quinn M. 343.08, 418.04

Konstantopoulos, Iraklis 152.07, 312.05 Koo, Bon-Chul 251.29 Koo, David C. 211.04 Koopman, Kristen 154.05 Koopmann, Rebecca A. 149.28 Koopmans, Leon V. E.. 225.01 Kopparapu, Ravi 343.22 Kopparapu, Ravi Kumar 415.03 Kormendy, John 241.12 Kornei, Katherine 325.04 Korngut, Phillip 227.05D Korpela, Eric 241.01, 241.02 Korpela, Eric J. 241.03, 241.04, 241.06, 251.29 Korpela, Matthew 339.24 Koshy, Sam 333.07, 430.19 Koss, Michael 142.29, **326.02D** Koss, Michael J. 142.50 Kotani, T 157.03 Kotulla, Ralf 211.06 Kouveliotou, Chryssa 434.01 Kovacs, Gabor 253.02 Kovtyukh, Valentin 342.17 Kowalski, Adam 242.24, 342.07 Kowalski, Adam F. 242.13, 307.02D Kowalski, M. 249.09 Kowalski, M 249.10 Kowalski, M. 308.01 Kowalski, Marek 308.04, 308.05D Kowalski, M 337.13 Kozhurina-Platais, Vera 254.37, 254.39, 254.40 Kozlowski, Szymon 430.16 Krabbendam, Victor 252.03, 252.05, 334.11 340.13 Kraemer, K E. Kraemer, Kathleen E. 342.01 Kraemer, Steven B. 142.13, 142.14, 142.15 Kraft, Ralph 142.18, 335.26 Kraft, Ralph P. 125.05, 142.20 Krajci, Tom 338.14, 340.27 Krajnović, Davor 335.08 Krajnovic, Davor 422.02D, 422.04 Kramer, Carsten 246.11 Kramer, Michael 139.05, 234.01, 234.05 Krane, Thomas 213.01 Kratochvil, Jan M. 225.02 Kratter, Kaitlin M. 258.10 Kratzer, Rachael 347.04

153.06, 153.07, 220.01, 340.05 Kraus, Adam Kraus, Adam L. 153.05, 302.03, 302.04 Krause, O 202.03 Krause, Oliver 255.15 Kreckel, Kathryn 211.03D Krejny, Megan 251.22 157.18 Krejny, Megan M. Kretke, Katherine A. 113.06 Krick, Jessica 109.05 Krimm, Hans 434.01 Krips, Melanie 335.21 Krishnamurthy, K. 256.12, 256.13 Kristensen, Lars 258.05 Krueger, Brendan K. 308.02, 337.01 Kruger, Andrew J. 406.05D Krughoff, K. S. 252.07 Krughoff, Simon 156.05, 252.08, 252.13, 252.21, 252.25, 344.09, 344.12 Krughoff, Simon K. 252.18 Krugler, Julie A. 242.12 Kruk, Jeffery 254.10 Kruk, Jeffrey W. 254.12 Krumholz, Mark 132.04D, 258.06 Krumholz, Mark R. 258.10 248.03 Kruse, Brian Kruse, Ethan 335.09 Kryukova, Erin 411.01 Kubik, Donna 239.04, 347.02 Kubo, Jeffrey 347.01, 347.02 Kubo, J 347.03 Kuchar, Thomas A. 342.01 Kuchner, Marc 253.10 Kudo, T 339.05 Kuehn, Charles A. 311.03D Kuehn, Kyler 239.01 Kuehn, Kyler W. 239.03 Kuemmel, Martin 335.19 Kuhlmann, Stephen 252.20 Kuhlmann, Stephen E. 239.03 Kuhn, Jeffrey R. 436.02 Kuijken, Konrad 241.12 Kuiper, Lucien 144.24 Kuk, K. 239.04 Kulkarni, Shri 157.11 Kunder, Andrea 150.01 Kunder, Andrea M. 241.12 Kundert, Kara 139.01

Kundu, Arunav 409.02D, 409.03 Kundu, Mukul 146.08 Kundurthy, Praveen 253.06 Kunkel, William E. 424.05 Kuntschner, Harald 312.02D, 335.19, 422.04 Kuntz, K. D. 114.07 Kuntz, Kip D. 246.10, 344.17 Kuo, Cheng-Yu 142.57, 408.06D Kuraszkiewicz, Joanna 230.04 Kurczynski, Peter 233.04 Kurgatt, Charles 342.12 Kuropatkin, N. 239.04 Kurtz, D. W. 103.07 Kurtz, Michael J. 116.08 Kurucz, Robert 254.12 Kutyrev, Alexander S. 142.49, 157.07, 254.10 Kuulkers, Erik 144.24, 434.01 Kwa, Anna 153.11 Kwitter, Karen 256.09 Kwitter, Karen B. 256.07, 256.08 Kwon, YongChul 344.12 Kyeong, Jaemann 433.08 Labattaglia, Rachel 346.02 229.06 Labbe, Ivo Lablanche, Pierre-Yves 422.04 Lacasse, Remi 420.02 Lacy, Claud H. S. 246.09 Lacy, John 258.08, 339.06 Lacy, M. 252.17 Lacy, Mark 331.04, 335.51, 430.25 Lafrenière, David 226.01 Lafreniere, David 418.08 Lagache, Guilaine 255.05 Lagattuta, David J. 225.01, 430.12 LaGue, C. 344.08 Laguna, Pablo 432.15 340.08 Laher, Russ Lähteenmäki, Anne 212.01 Lahteenmaki, Anne 408.04 Lai, David 153.11 Lai, David K. 327.05 Lai, Kamson 211.04 Laine, Seppo 256.33, 309.01D, 335.46 Laird, Jacqueline 247.08 Lake, Sean E. 333.16 Lal, Dharam V. 125.05

Lallement, Rosine 251.31 Lalmansingh, Jared 140.11 Lam, Michael T. 142.09, 142.10 LaMassa, Stephanie M. 230.06D Lamb, Joel B. 327.06 Lambert, David L. 256.23 Laming, J. Martin 130.05 LAMOST Project of China, 334.13 254.12, 433.03 Lampton, Michael Lampton, Michael L. 433.04 Landolt, Arlo U. 338.14 Landsman, Wayne B. 152.12 Lane, Benjamin F. 144.16, 429.09 Lane, Richard 152.28 Laney, C. D. 144.11, 157.13 Lang, Cornelia C. 241.07, 241.08 Langley, Chris 413.01 Langston, Glen 215.01, 349.02 Lanyi, Gabor 156.01 Lanz, Thierry 152.12 Laor, A. 142.06 Laorr, Anna 248.13, 340.08 Larionov, Vladimir 212.01 Larionov, Valeri M. 142.37, 142.55, 408.04 Larkin, James 241.18, 407.06 Larkin, Mikaela 139.01 Larsen, Jeffrey A. 241.10 Larsen, Soeren 327.03D Larsen, Søren S. 312.02D Larson, Ana 248.14 Larson, Elise 430.03 Larson, Kirsten 335.30 Larson, Kristen A. 250.06 Larson, S 334.17 LAT Collaboration, 336.07 Latham, David 140.05 Latham, David W. 103.04 Latham, D. W. 103.07 239.04 Lathrop, A. Lattimer, James M. 234.04D 433.10 Lau, Judy Lauer, Tod 422.05 Lauer, Tod R. 422.06 Laugalys, Vygandas 340.11 Laughlin, Gregory 140.19, 220.03 Laughlin, Greg 343.08

Launhardt, Ralf 202.03 Law, Casey J. 240.01 Law, David R. **211.05**, 325.03, 335.06 Law, Ka Hei 258.24 Law, Nicholas 153.06 Law, Nick 153.07 Law, Nicholas 157.11 Law, Nicholas M. 153.05, 220.01, 403.06 Lawler, James E. 349.06 Lawler, M. J. 248.01 Lawler, Samantha 306.03 Lawrence, Andrew 213.01 Lawrence, Andy 433.22 Lawrence, Charles 142.38, 230.04 P243.01, P243.02, P243.03, P243.04, P243.05, P243.06, P243.07, P243.08, P243.09, Lawrence, Charles R. P243.10, P243.11, P243.12, P243.13, P243.14, P243.15, P243.16, P243.17, P243.18, P243.19, P243.20, P243.21, P243.22, P243.23, P243.24, P243.25, P243.26, P243.27 Lawton, Brandon L. 251.27 Laycock, Silas 434.08 Layman, Steven 158.05 Lazar, Jozsef 253.02 Lazarian, Alex 104.06 Lazarian, Alexander 251.02 Lazarus, Patrick 234.01, 234.05 Lazear, Justin 313.05 Lazendic, Jasmina S. 256.14 Lazio, Joseph 107.09, 241.08 Lazio, T. J. 343.25 Le Floc'h, Emeric 335.38 Leadbeater, Robin 257.04, 257.05 Leahy, Denis A. 311.06 leake, Martha A. 156.11 Leake, Sean 336.12 Leaman, Ryan 147.05 Leaveck, Katherine 433.21 Lebouteiller, V. 254.21 Lebouteiller, Vianney 254.22 Lebrón, Mayra 434.33 LeDuc, Henry G. 413.04D Lee, Brian 242.29, 334.12 249.02 Lee, Dae Hee Lee, D.H. 249.03 Lee, Eve J. 251.14, 258.13 Lee, Hyung Mok 430.33 Lee, Jeewon 430.21 Lee, Jeongae 430.21

Lee, Khee-Gan 412.03D Lee, Kevin M. 247.01, 247.06 Lee, Myung Gyoon 152.04 Lee, Min-Young 241.01, 241.02, 241.03, 241.04, 241.06 Lee, Myung Gyoon 430.33 Lee, Nicholas 335.38 Lee, Tae Song 421.05 Lee, Young Sun 241.10, 434.49 Lee, Young S. 334.13 Legassie, Mark 340.08 Lehan, Cory 344.01 Lehman, Emma M. 256.08 Lehmer, Bret 245.15 Lehner, Nicolas 345.09 Leibler, Camille N. 141.02 Leighly, Karen M. 142.45 Leiner, Emily M. 343.05 Leipski, Christian 230.04 Leisawitz, David 333.04, 333.05, 333.10, 333.12 Leisawitz, D. T. 333.08, 333.09 Leisenring, Jarron 406.02D Leising, Mark D. 145.10 Leisman, Luke 149.08 Leitherer, Claus 245.02 Lemaux, Brian 114.03, 430.25 Lemay, Damien 420.02 Lemon, Courtney 145.07 Lemonias, Jenna 153.06, 153.07 Leonard, Douglas C. 337.21, 434.30 Lepine, Sebastien 226.06, 242.11 Lépine, Sébastien 242.17 Lepine, Sebastien 307.05D, 348.01 Lequeux, James 146.08 Leroy, Adam 241.02, 246.11, 258.28, 331.03 Leroy, Adam K. 133.04D, 202.07, 246.14 Lesniak, Michael V. 340.06 141.01 Levan, A. J. Levan, Andrew J. 108.02D Levandowski, Kirsten 142.09 Levato, Hugo 339.24 344.07 Levay, Karen Levay, Zoltan G. 251.16 Levenson, Louis 249.03 Levenson, Louis R. 249.02 Levenson, NA. 157.03 Levesque, E. M. 141.01

Levi, Michael 433.03 Levi, Michael E. 433.02, 433.04 Levine, Bruce 253.11 Levine, Robyn D. 335.24 Levine, Stephen E. 306.05 Levison, H. F. 113.06 Lewin, Walter H. G. 432.12 Lewis, B. M. 433.13 Lewis, Geraint F. 152.28 Lewis, KT. 142.54 Lewis, Mark C. 435.01 Li, Di 112.07, **416.01** Li, Guangwei 334.13 Li, Hui 149.05 Li, Jie 140.05 Li, Weidong 310.08, 324.04, 324.05 Li, W. 337.21 Li, Weidong 337.26 Liang, Edison 142.51 Liang, Edison P. 434.03 Liang, Ming 252.05 Licandro, Javier 306.06 Lidman, C. 249.09 249.10 Lidman, C Lidman, Christopher 308.05D 337.28 Lien, Amy Y. LIGO Scientific Collaboration, 432.27 LIGO Scientific Collaboration, Virgo Collaboration, 225.03 Lillie, Charles 425.05 Lim, Eugene A. 225.02 232.05 Lim, Jeremy Lim, Pey Lian 254.16 Lim, Pey-Lian 344.16 Lim, Sungsoon 152.04 Lim, Yeunhwan 234.04D Lin, Doug 253.10 Lin, Dacheng 432.17, 432.25 Lin, Doug N. C. 415.06 Lin, Huan 239.04, 245.12, 334.03, 347.01, 347.02, 347.03 Lin, Hsing-Wen 435.02 432.26 Lin, Jinrong Lin, Yen-ting 222.07, 230.05 Linder, E 249.10 Linder, Eric V. 151.05 Linder, E. V. 249.09 Lindler, Don 254.18, 430.24, 434.17

Linford, Justin 142.44 Ling, Zhu 430.41 Linnell, Albert P. 338.04, 338.05 Linsky, Jeffrey 339.18 Linsky, Jeffrey L. 258.11, 339.13 Lintott, Chris 142.08, 158.13, 247.05 Lintott, Chris J. 106.04, 252.04 Linz, H 202.03 Lippok, H 202.03 Lira, Paulina 230.01 Lira, P. 252.17 LISA International Science Team, 347.07 Lisenfeld, Ute 325.05 Liskowsky, Joseph P. 434.21 Lisman, Doug 253.12, 254.29 Lissauer, Jack J. 103.03, 103.05, 140.13 Lisse, Casey 202.01 Lisse, Carey M. 349.04 212.02D, 230.07 Lister, Matthew Lister, Matthew L. 142.34, 310.03 Lister, Tim 220.01 Lithwick, Yoram 415.07 Little, Bert 433.21 LITTLE THINGS Team, 147.13, 147.15, 328.03D Littman, Michael 254.32 Liu, Guilin 246.04 Liu, Jiayi 334.03 Liu, Mike 226.01 Liu, Michael C. 253.10, 307.01, 340.28 Liu, Wenhao 116.04 Liu, Wilson 333.05 Liu, Zheyu J. 152.18 Livengood, Timothy A. 349.04 Livingston, John 142.38 Livio, Mario 251.16 Llamas, Jacob 420.03, 420.04 Lloyd, James P. 343.02, 401.03D Lo, Amy 253.07, 425.05 Lo, Fred 142.57 Lo, Fred K. 408.06D Lo, Nadia 113.04 Lo, T. 344.08 Lo, Ying-Yi 434.39 Lo Presto, Michael C. 247.09 Lockhart, Matthew 306.05 LoCuSS, 430.38

Lodder, Katherine 256.29 Lodders, Katharina 402.01 Loeb, Abraham 107.03 Loeb, Avi 107.09 Loebman, Sarah 241.11 Loebman, Sarah R. 248.14 Logsdon, Sarah 434.11 Loinard, Laurent 434.44, 434.46 308.01 Loken, S. Loken, Stu 308.04 Loken, S 337.13 Lommen, David 340.35 Londhe, Rucha 431.05 Long, Knox 254.41 Long, Knox S. 256.19, 256.21, 256.22, 256.32 Longo, Giuseppe 433.22 Lonsdale, Carol J. 335.51 Looney, Leslie W. 133.05, 340.17 Looper, Kristina 311.03D Loose, Markus 254.18 Lopez, Eric 343.17 Lopez, Laura A. 132.04D, 335.08 Lopez-Cruz, Omar 149.03 201.04 Lopez-Morales, Mercedes López-Morales, Mercedes 242.03 Lopez-Morales, Mercedes 242.23, 415.04 Loredo, Thomas J. 418.02, 432.11 Lorentz, Suzanne 252.21 Lorenz, Suzanne 151.01, 252.07, 252.08, 252.18, 252.25 Lorimer, Duncan 145.06, 234.05 Lorimer, Duncan R. 234.01 Los, Edward 201.07 Lotkin, Gennadiy 157.07 Lotz, Jenifer 149.19 256.14 Lovchinsky, Igor 313.05 Lowe, Luke Lowe, Stuart 145.01 LSST Collaboration, 252.01, 252.02, 252.05, 252.12 LSST Galaxies Collaboration. 252.16 LSST Informatics and Statistics Team, 252.09 LSST LSS Science Collaboration, 252.19 LSST MWLV Collaboration, 252.14 LSST Outreach Advisory Board, 252.04 LSST Solar System Science Collaboration, 252.10 LSST Stellar Populations Collaboration, 252.15 LSST Strong Lensing Science Collaboration, 252.21, 252.22 LSST Supernova Collaboration, 252.20 LSST Weak Lensing Science Collaboration, 252.23 Lu, Jessica 145.03 Lu, Jessica R. 241.18, 303.04, 411.02 Lu, Wenxian 342.10 Lubin, Lori 114.03 Lubin, L. 249.09 308.05D Lubin, Lori Lubin, Lori M. 430.25 Lubin, Philip 434.52 Lubin, Philip M. P243.28 339.10 Lubow, Stephen H. Lucas, Ray A. 335.01 Lucatello, Sara 153.11 325.03 Ludlum, Kevin Ludovici, Dominic 254.22 Ludovici, D. A. 254.21 Luker, Jay 116.08 Lukic, Zarija 127.04 Lund, Niels 434.01 Lunn, Martin 111.03 Lunnan, Ragnhild 230.05 Luo, A.-Li 334.13 244.02 Lupu, Roxana Lupu, Roxana E. 245.14 Lust, Nate B. 402.02, 418.02 Lutz, Dieter 202.08, 245.12 Lutz, Julie 247.09, 256.06, 256.09 Lutz, Julie H. 248.09 LVL Team, 147.11, 147.12, 309.05, 335.28 335.13 Ly, Chun Lykke, Keith R. 157.15, 348.03 Lynch, Christene R. 319.04 Lynch, David 257.09 Lynch, Dana H. 254.06 Lynch, Ryan 158.05, **215.03D** Lyne, Andrew 234.05 Lyne, Andrew G. 139.05, 234.01 Lynn, Stuart 142.08 Lyon, Richard 253.11 Lyons, Daniel J. 405.04, 405.05 Ma, Bo 242.29, 334.12 Ma, Chung-Pei 407.06, 422.06 Ma, Yin-Zhe 313.01D Ma, Zhaoming 433.16 Mac Low, Mordecai-Mark 144.18, 216.01

Mac Low, Mordecai M. 251.06 Maccarone, Thomas J. 144.24, 409.02D, 409.03 MacDonald, Christopher J. 227.02 144.20 MacDonald, Rachel K. 343.23, 434.20 MacGregor, Keith B. MacGregor, Meredith A. 245.06 Machacek, Marie E. 148.01 Machalek, Pavel 201.02 Machenschalk, Bernd 234.01 Macias, Phillip 143.04 Maciejewski, Witold 142.46 Maciel, Tamela 430.26 Macintosh, Bruce 253.12, 302.01, 418.04, 418.05 Macintosh, Bruce A. 339.04, 343.08 Mack, Claude 334.12 Mack, Jennifer 254.39, 254.40 Mack, Katherine J. 345.03 MacKenty, John 254.16, 254.37, 254.38, 254.39 MacKenty, John W. 254.36 MacKenzie, Shannon 149.09 MacLeod, Chelsea 430.16 MacLeod, Chelsea L. 230.02 Macnaughton, Ron 420.02 Macomb, Daryl 157.01 Macomb, Daryl J. 144.28 MacQueen, Phillip 201.02 Macri, Lucas 150.02, 342.06 Macri, Lucas M. 311.05 Madau, Piero 421.07D Maddalena, Ron 202.09, 245.08 Maddalena, Ronald J. 344.10 Madejski, G. M. 252.17 Maderak, Ryan M. 152.38 Madhusudhan, Nikku 402.02, 402.08, 418.01, 418.02, 418.03 311.04 Madore, Barry Madore, B.F. 344.08 Madore, Barry F. 148.06 Madsen, Gregory J. 251.05 Madsen, G. J. 251.07 Madsen, G J. 251.09 Madsen, Kristin 254.13, 333.11 Madsen, Kristin K. 430.12 Madura, Thomas 338.17 Magalhaes, Mario 434.34 MAGMA collaboration, 216.05 Magnani, Loris 434.37

Magneville, Christophe 252.19 Mahabal, A. 252.09 Mahabal, Ashish 334.02 334.17 Mahabal, A Mahabal, Ashish 344.11 Mahadevan, Suvrath 220.03, 242.29, 253.09, 401.01 Mahajan, Smriti 233.02D Mahdavi, Andisheh 109.06 Mahdevan, Suvrath 401.02 Mahmud, Naved 253.13, 253.14 Mahmud, Niyaz 340.08 Mahmud, N 343.01 Mahmud, Niyaz 346.07 Maia, Marcio 430.04 Maier, Gernot 144.29 Maina, Edwin 342.11 Mainzer, Amy 333.03, 333.18 Maiolino, Roberto 254.27 Majeau, Carl 343.13 Majewski, Steven R. 307.04D, 409.05, 424.05 Maldonado, Sergio E. 433.02 Malhotra, Sangeeta 335.17, 335.19, 335.43, 335.45, 407.03 Malkan, Matt 407.07, 407.08 142.46, 310.08, 335.13 Malkan, Matthew A. Mallard, William 240.06 Mallery, Ryan 241.12 Mallory, Carolyn 340.08 346.07 Mallory, Carolyn R. Malmrose, Michael 430.20 Malone, Christopher M. 234.03D Maloney, Philip R. 413.04D Malumuth, Eliot 434.17 Malville, Kim 146.11 Mamajek, Eric 253.10 Mamajek, Eric E. 343.14 Manchester, Richard N. 139.05 Mandel, Ilya 225.03 Mandel, Kaisey 324.01 Mandelbaum, Rachel 227.01, 227.02, 430.06 Mandell, Avi 402.08 429.07 Mandushev, Georgi Manera, Marc 249.07, 249.08 Mangum, Jeffrey G. 245.06 Manley, Jason 432.06 Manning, Anna 106.04, 142.08 Manning, Jim 209.06

Manset, Nadine 339.24 Manukian, Haik 149.13 Mao, Jirong 108.04 Mao, Peiyuan 140.14 Mao, Sui 217.03D Mao, Shude 347.09 Maraschi, Laura 408.01 Marchen, L. 253.12 Marchwinski, Robert 241.15 Marcy, Geoff 103.03 Marcy, Geoffrey 343.21 Marcy, Geoff 415.06 Marcy, Geoffrey 434.12 Marcy, G. W. 103.07 Marcy, Geoffrey W. 434.30 Marengo, Massimo 130.01, 434.19 Maret, Sebastien 255.15 Margheim, Steven J. 427.02 Margon, Bruce 430.13 Margoniner, Vera E. 335.32 Margot, Jean-Luc 306.01 Marine, Hannah 142.24 Markert, Sean 147.09 Markevitch, Maxim 127.01D Markoff, Sera 230.02 Markov, Harry 429.07 Markowitz, Alex 430.17 Marksteiner, Quinn 234.06 Markwick, Andrew J. 114.06 Marley, Mark S. 343.14 Marois, Christian **302.01**, 343.08, 418.04, 418.05 425.01 Marr, James Marr, Jonathan M. 142.31, 346.10 Marrone, D. 323.06 Marscher, Alan 212.01 Marscher, Alan P. 142.37, 142.55, 142.64, 408.04, 430.20 Marsden, Brian 146.11 Marsden, Danica 325.02D Marshall, Herman 230.07 Marshall, Herman L. 254.11 Marshall, J. L. 433.09 Marshall, Jennifer L. 433.12, 434.30 Marshall, Kevin 142.19, 142.24 Marshall, Philip J. 252.21, 252.22, 347.05 Marshall, Phillip J. 430.01 Marshall, Stuart 239.03, 252.02, 252.07, 252.18, 252.21, 252.25

Marshall, Sean 333.02 Marshall, Stuart L. 252.08 Martell, Sarah L. 327.05, 434.49 Martimbeau, Nathalie 158.08 149.09 Martin, Chris Martin, C. 323.06 Martin, Chris 333.17 Martin, Christopher D. 426.04 Martin, Christopher L. 255.06, 255.07 Martin, Crystal L. 325.04 Martin, D. Christopher 426.01D Martin, John C. 154.12 Martin, Robert 413.06 Martin, Rebecca G. 339.10 Martin, Victoria 222.06 Martinez, Jose 336.12 Martini. Paul 213.04D Martino, Danielle L. 247.09 Marvel, Kevin B. 248.03 Marzke, Ron 430.04 Marzoa, Ramon I. 201.04 Masci, Frank 333.15 Masci, Frank J. 333.12 345.06 Maseda, Michael Masetti, Margaret 248.08 Masiunas, Lauren 258.21 Mason, Brian 151.03 Mason, Brian D. 146.06 Mason, Brian S. 227.05D Mason, Peter 249.02 Massa, Derck 254.01, 254.02, 254.03, 254.28 Masseron, Thomas 153.11 Massey, Philip 153.16, 242.07, 251.12 Massey, Richard 109.05 MAST Team, 344.07 Masters, Karen 150.02 Mata, Alberto 336.12 Matche, Lissa 248.13, 340.08 Mathes, Nigel 345.05 Matheson, Thomas 337.26 Matheson, Tom 337.32 Mathieu, Robert 144.17 Mathieu, Robert D. 152.31, 152.34, 327.02 Matsuda, Yuichi 430.37 Matsumoto, Toshio 249.02, 249.03 Matsumuura, Shuji 249.03

Matsuo, T 157.03 Matsuura, M 157.03 Matsuura, Shuji 249.02 Matt, Sean 434.20 Matthew, Rickert 332.01 Matthews, Brenda 255.01 Matthews, Jaymie 242.24, 429.08 Matthews, Keith 241.18, 303.04 Matthews, Lynn D. 155.02, 434.19 Matuszewski, Mateusz 426.01D Matuszewski, Matt 426.04 Matzner, Christopher D. 132.07, 258.10, 427.04 Mauclaire, B. 257.04 Maukonen, Douglas 202.01 Maune, Jeremy 142.24 Max, Claire E. 310.05 Max-Moerbeck, Walter 142.01, 142.02 Maxted, Pierre F. L. 402.02, 418.02 May, Morgan 225.02 May, Sara K. 248.06 Maybhate, Aparna 152.07 Mayer, Lucio 421.07D Mayer, Michael 248.07 Mayes, Deronda 156.12 Mayo, Elizabeth A. 145.10 Mazin, Benjamin A. 413.04D Mazzali, Paolo 337.32 Mazzarella, J.M. 344.08 McAlister, Harold 242.03 McAlister, Hal 257.03 McAlister, Harold A. 343.07, 415.04 McArthur, Barbara 415.01 McArthur, Barbara E. 152.40, 242.25 McBride, Cameron 249.06, 249.07 McBride, Cameron K. 249.08 McBride, James 245.11 McCabe, Caer 340.24 McCandlish, Samuel 347.06 McCandliss, Stephan R. 254.10, 254.12 McCanna, Taylor 248.13, 340.08 McCarrick, Heather 241.17 McCarron, Kevin 248.13, 340.08, 346.07 McCarthy, Donald 145.07 McCarthy, Patrick 149.19, 407.07 McCarthy, Pat 407.08 McCarthy, Patrick J. 335.18, 335.19

McCartney, Anna	248.13, 340.08
McCauliff, Sean 140.01	
McCleary, Jacqueline E.	246.16
McClellan, Randall E.	311.03D
Mcclintock, Jeffrey	432.14
McClintock, J E. 143.04	
McClintock, Jeffrey E.	404.02
McClintock, Ryan P.	425.06
McCluskey, Jr., George E.	144.05
McComas, Dave	434.34
McConnachie, Alan	152.03
McConnell, Adam	335.34, 335.35
McConnell, Nicholas J.	422.06
McConville, William	106.03D
McCormick, Jennie	338.14
McCormick, Kristina	147.05
McCrady, Nate 411.02	
McCullough, Peter	429.07
McCully, Curtis 337.10	
McDermid, Richard	312.04, 422.04
McDermid, Richard M.	335.08, 422.02D
McDonald, Michael	127.03D
McElwain, Michael W.	429.10
McEntaffer, Randall L.	256.31
McFadden, Lucy	349.04
McFall, Michael 338.20	
McFall, Michael J.	241.13
McGaugh, Stacy 430.26	
McGee, Ryan P243.28	
McGehee, P. 252.14	
McGehee, Peregrine	252.15
McGonigle, Lorcan P.	433.14
McGrath, Elizabeth J.	211.04, 422.01
McGraw, John T.	157.05, 157.15 , 348.03
McGurk, Rosalie C.	310.05
McIntosh, Daniel H.	335.34, 335.35, 335.47
McIntyre, Travis P.	246.18
Mckay, Timothy	213.06
McKean, John P.	225.01
McKeever, Jeanne	248.09
McKeever, Jean 256.09	
McLaughlin, Maura	139.02, 139.03, 145.06, 209.08 , 234.05
McLaughlin, Maura A.	234.01
McLean, Ian S. 132.06	
McLinden, Emily	335.43 , 407.03
McMahon, Nicholas	246.02
McMahon, Peter 240.06 McMaster, Laura 338.12, **338.13** McMillan, Russet 257.05 McMillan, Stephen L. W. 152.15 McMullin, Joseph P. 413.01 McMurtry, Craig 343.14 McNamara, Brian 142.18 McPhate, Jason 254.03 Mcswain, Ginny M. V. 406.03 McSwain, M. V. 144.10, 152.33, 342.05 McWilliam, Andrew 242.25, 328.04D Meade, Marilyn 241.14, 241.16 Meade, Marilyn R. 339.22 Meadows, Victoria S. 220.07, 343.09, 349.04 Measurement Astrophysics Research Team, 157.15 Mechtley, Matt 142.40 Meech, Karen J. 306.07 Meegan, Charles A. 434.01 MeerKAT Deep HI Survey Team, 433.17 Megamaser Cosmology team, 408.06D Megeath, S.T. 411.01 Megeath, S T. 340.04, 340.13 Megeath, Tom 255.04, 255.15, 258.19, 258.21 Megeath, Thomas S. 157.04 Mehner, Andrea 154.12, 232.04D 312.03 Mei, Simona Meidt, Sharon 207.07, 246.11 Meier, David 142.38, 251.26 Meiksin, Avery 142.16 Meisner, Aaron 430.16 Meixner, Margaret 232.01, 258.28, 337.22 Melchiorri, Riccardo 319.07 Meldgin, David R. 252.22 Melendez, Marcio 142.13 Melis, Carl 322.05, 339.17, 434.15 Melo, Claudio 340.22 222.07 Mena, Olga Mendez, Bryan 158.09 Mendez, Mariano 144.24, 432.12 Mendygral, Peter 125.06 Meneghetti, Massimo 109.05 Menendez-Delmestre, Karin 325.03 Menon, Athira 341.06 Menou, Kristen 302.07 Menten, Karl 430.11 Menten, Karl M. 113.01

Menzel, Raymond L. 339.07 Meredith, Kate 142.43, 248.12 Merin, Bruno 339.09 242.10 Merritt, Allison T. Merritt, David 335.48 Merten, Julian 109.05 Messenger, Chris 234.01 Messenger, Scott 434.41 Metcalfe, Travis S. 201.08 Metchev, Stanimir 253.03 Metzger, Alicia 334.08 Meurer, Gerhardt 335.19 Meurer, Gerhardt R. 246.13 Meyer, Eileen T. 212.02D Meyers, J. 249.09 Meyers, J 249.10 Meyers, Joshua 308.05D Meyers, Phil 258.21 Mezzacappa, Anthony 337.23, 410.02D Michael, Adam 251.21 Middelberg, Enno 142.32 Middleditch, John 234.06, 336.01, 337.34 Mierkiewicz, E. J. 251.07 Mierkiewicz, E J. 251.09 Miesch, Mark S. 155.12, 242.22 140.11, 140.15, 342.13 Mighell, Kenneth Mighell, Kenneth J. 145.10 Mihos, J. C. 149.25 Mikles, Valerie J. 144.21, 144.24 Mikles, V J. 152.05 Mikula, Julie 253.12 Milani, Andrea 252.10 Milingo, Jacquelynne B. 256.07 Milisavljevic, Dan 337.19 Milky Way Project Team, 251.15 Miller, Andy 336.12 Miller, Brendan P. 142.53 142.54 Miller, B P. Miller, Brendan P. 148.05 Miller, Bryan W. 152.08 344.13, 430.31 Miller, Christopher Miller, Daniel 141.04, 141.06 Miller, H. Richard 142.24 Miller, Jacob 142.35 Miller, Lucas 250.16 Miller, Lissa R. 241.17, 433.18

Miller, M. C. 105.07 Miller, Neal A. 149.18 Miller, Rossina 336.12 Miller, Sarah 335.40 Miller, Timothy 313.05 Miller-Ricci Kempton, Eliza 418.08 Milliard, Bruno 426.04 Milne, Marie 429.02 308.01 Milne, P. Min, Koung-wook 251.17 Min, Kyoung Wook 251.24 Minchev, Ivan 323.03 Minchin, Robert 246.06 Minchin, R. 246.18 Minchin, Robert 434.33 Minchin, Robert F. 149.23 Miner, Jesse 211.02D Minezaki, T 157.03 Mink, Doug 153.03 Minniti, D. 252.14 Minniti, Dante 252.15, 337.32 Minns, Cody 147.11 Minns, Cody R. 147.12 434.46 Mioduszewski, Amy J. Mirel, Paul 313.05 433.06 MIRI Team, Miroshnichenko, Anatoly S. 339.24 Misawa, Toru 345.04 Misra, K. 141.01 Mitchell, Carl 144.10 Mitchell, Daniel 116.07 Mitchell-Wynne, Ketron 249.03, 255.09 Mitra, Dipanjan 336.09, 336.11 Mitschang, Arik W. 154.10 Miyazaki, A. 323.06 Mizuno, D 340.13 Mizuno, Donald R. 342.01 Mizusawa, Trisha 207.06, 246.01 335.34, 335.35 Mo. H. J. Mo, Wenli 244.03 Mobasher, Bahram 128.06, 334.05, 430.23 335.39 Mocz, Philip Moderski, Rafal 106.03D Moeckel, Nickolas 416.04 Moffat, Anthony F. J.. 144.26 Moffett, Amanda J. 334.14, 334.15, 335.46

Moffett, David 256.26 334.03 Mohr, Joseph Moiseev, Alexei 335.49 MOJAVE Collaboration, 310.03, 408.07 Moldenhauer, Jacob 432.05 Molinari, Sergio 202.02 Molinari, S. 255.03 Momcheva, Ivelina G. 149.19 Momjian, Emmanuel 245.10 Momjian, E. 246.18 Momjian, Emmanuel 332.01 Momose, Rieko 246.04 Monard, Berto 338.14 Moniez, Marc 252.19 Monnier, John D. 257.03 Monroe, TalaWanda 406.01 Monson, Andy 311.04 Montaruli, Teresa 142.60 Montenegro, Maximiliano 434.40 Montes, J. 239.04 Montet, Benjamin 251.02 Montez, Rodolfo 232.06D Montgomery, Micheal 341.05 Montgomery, M H. 433.24 Montgomery, Sharon L. 339.11 Moody, J. W. 157.13 Moon, Dae-Sik 427.04 Moon, Jared 241.08 Moore, Anna 426.04 Moore, David 432.06 Moore, Joseph 158.13 Moore, Marilyn **338.12**, 338.13 Moore, Toby 411.04 Moorhead, Althea 103.06 Moorhead, Althea V. 103.05, 343.18 Moos, H. W. 254.12 339.08 Morales, Farisa Y. Morales, Maria 340.21 Morales, Miguel F. 150.03 Morales-Calderon, Maria 144.22, 340.32 Moreau, Julie 241.15 Moreau, Julie M. 251.04 Morehead, Robert 103.06, 140.09 Morehead, Robert C. 103.05 Morell, Nidia I. 434.30 Moreno, Jackeline 338.08

222.03 Morgan, Jeffrey S. Morgan, Lawrence 411.04 Morgan, Robert J. 433.23 346.08 Morgan, Windsor A. 334.04 Morganson, Eric P. Morganti, Raffaella 115.04, 422.04 Morin, Auralee 142.09 Morisset, Christopher 157.07 Mork, Kayla 248.13, 340.08 Morokuma, T. 249.09 Morokuma, T 249.10 Morokuma, Tomoki 308.05D Morozova, Daria 142.55 Morrell, Nidia 242.07 Morris, Frank 346.05 Morris, Mark R. 241.18 Morrison, Glenn 335.21 Morrison, H. L. 149.25 Morrison, Michael A. 256.07 Morrison, Nancy D. 154.11 Morrison, Sean 140.15 Morrison, William A. 142.26 Morrissey, Patrick 426.03, 426.04 Morsony, Brian 142.35 Morton, Tim 429.06 Morzinski, Katherine 306.05 Morzinski, Katie M. 226.02D Moseley, Harvey 254.27, 313.05 Moseley, Samuel H. 157.07 Moseley, S. H. 254.10 Moseley, Samuel H. 254.18 Mostardi, Robin E. 335.42 341.06, 341.07 Motl, Patrick Motl, Patrick M. 126.03 254.12 Mott, D. B. Motte, F 340.13 Moustakas, John 213.05, 229.01D Moustakas, Leonidas 109.05, 227.06 Moustakas, Leonidas A. 403.07 Moutou, Claire 418.08 Mozena, Mark 211.04 Mozurkewich, D. 242.06 Mroczkowski, Tony 227.05D MTakamiyaUHH, 114.01 Muders, Dirk 216.06 Mufson, Stuart 430.24

Muirhead, Philip 401.03D Mukadam, Anjum S. 126.06 Mulally, Susan 341.05 Mulchaey, John 149.13 Mulchaey, John S. 310.04 Mullally, Fergal 103.01, 140.03 Muller, Erik 251.26, 258.28 Mundt, Reinhard 340.01 Mundy, Lee G. 340.10 Munetake, M 339.05 Munoz, D. 323.06 Munoz, R. 252.14 Munoz, Ricardo R. 424.05 Munoz-Mateos, Juan Carlos 207.06, **417.02D** Munsell, Jeremy 142.04 Munshi, Dipak 249.04 Munshi, Ferah 328.05 Murchison Widefield Array Team, 155.02 Murillo, Luis F. 431.06 Murison, Marc A. 156.06 Murphy, Brian W. 152.18, 241.13 Murphy, David 142.38 Murphy, David C. 340.31 Murphy, Ed 158.05 Murphy, Eric 417.08 Murphy, Eric J. 255.08 Murphy, Jeremy 151.02, 422.05 Murphy, Jeremiah W. 410.01 Murphy, Kendrah D. 254.11 Murphy, Simon J. 322.05 Murray, Claire 246.07, 251.12 Murray, Norman 216.03D, 251.14 Murray, Stephen S. 116.08, 256.27 Murray-Clay, Ruth 156.10, 418.03 Musher, Daniel 249.08 Mushotzky, Richard 125.01, 127.03D, 142.13, 142.29, 326.02D Mushotzky, Richard F. 125.02 Musielak, Dora 318.05 Musielak, Zdzislaw E. 318.05, 415.05 MUSYC Collaboration, 407.02 Mutchler, M. 158.06 Mutchler, Max 251.16 Mutel, Robert L. 105.05, 319.04 Muterspaugh, Matthew W. 429.09 Muzerolle, James 254.17, 254.27, 434.45 Myers, Adam 310.07

Myers, Adam D. 106.05, 222.05, 222.06, 310.04 Myers, Philip 340.35 Myers, Philip C. 340.31 Naab, Thorsten 422.04 Nagamine, Kentaro 142.48, 309.04, 335.05, 345.01, 421.05 Nagao, Tohru 430.10 Nagarajan, Satya 252.07, 252.08, 252.21, 252.25 Nagy, Sarah 335.06 Nagy, Sarah R. 211.05 Nahar, Sultana N. 434.40, 436.03 Nair, Preethi 430.27 Najita, J 157.03 Nakajima, Reiko 227.01, 227.02 Nam, UW. 249.02 NANOGrav, 139.06 Naoz, Smadar 415.07 324.01, 337.32 Narayan, Gautham Narayan, Ramesh 432.14 Narayanan, Anand 345.07 Natalucci, Lorenzo 434.01 Natarajan, Priyamvada 106.04, 116.03D Navarro, Robert 413.03 Naze. Yael 144.26 Neale, Patrick J. 349.01 Needles, Madeleine M. 248.06, 346.10 Neff, James E. 339.20 Negrello, Mattia 202.09 Negrello, Mattio 255.13 Neill, Don 148.06 Neill, Douglas R. 252.05 Neill, James D. 337.20 Neilsen, Joseph 404.01D Neira, Chantale 155.10, 155.11 Nejat, Cyrus 254.15 Nelan, Edmund 242.25 Nelan, Edmund P. 152.32 Nelemans, Gijs 144.24, 225.04, 337.18 245.02 Nell, Nicholas Nelson, Benjamin 343.20 Nelson, Johnathan 139.01 Nelson, Jocienne N. 139.01 Nelson, Lorne 324.03, 432.26 Nelson, Lorne A. 338.01 Nelson, Nicholas J. 155.12, 242.22 Nelson, Richard 322.03D nemati, Bijan 425.01

Nemiroff, Robert J. 141.04, 141.06, 158.03, 249.05 Nemmen, Rodrigo 310.01 Neri, Roberto 430.11, 430.23, 430.28 Nesmith, Eva 342.13 345.05 Nestor, Daniel Netzer, Hagai 230.01, 421.04 Neufeld, David 255.04, 255.15 Neugent, Kathryn 242.07 Newberg, Heidi J. 334.13 Newbury, Peter 158.08 Newgard, Arielle L. 112.05 Newhouse, Mark 158.10 Newman, J. A. 252.17 Newman, Jeffrey A. 252.19 Newman, Sarah 128.04 Newton, Elisabeth R. 347.05 Newton, Jack 337.18 Neyrinck, Mark C. 204.05D Ng, C.-Y. 256.14 Ng, Chi Yung 256.27 Ngeow, Chow-Choong 334.03 Ngeow, Chow 342.04, 342.18 Ngoc, Phan-Bao 242.18 Nguyen, Duy 242.29 Nguyen, Duy C. 334.12 Nguyen, Hien 244.02 Nguyen, My L. 310.08 NGVS Team, 152.03 Nhan, Bang 151.03 Nice, David 234.05 Nice, David J. 139.05, 139.06, 234.01 Nicholas, Earl 433.20 Nichols, Joy S. 154.10 Nidever, David L. 424.05 Nielbock, M 202.03 Nielsen, Eric L. 253.10 335.34 Nielsen, Jennifer L. Nielsen, Jennifer NielsenL. L. 335.35 Nielsen, Mikkel 337.18 Niemi, Sami 254.01 Nierenberg, Anna 430.01 Nigra, Lou 433.13 Nikutta, Robert 430.20 Nilsson, Kim 407.03 Nissanke, Samaya 225.04 NITARP Luminous Data Miners Team, 142.43

NITARP Team, 248.11 NOAO EPO Students, 248.07 Noeske, Kai 254.37 Noh, Yookyung 204.06 Noll, Keith S. 156.08, 251.16 Nonaka, Andrew J. 234.03D Nordby, Martin 252.02 Nordgren, Tyler E. 158.15 Nordin, Jakob 434.27 Noriega-Crespo, Alberto 131.01, 340.24, 411.05 Norman, Dara 142.27, 145.05 413.04D Noroozian, Omid Norris, Jay 157.01 Norris, Jay P. 108.03, 142.49 Norris, Mark A. 334.14 Norris, Ray P. 142.32 Norton, Timothy 254.19, 413.07 Nousek, John 425.02 Novak, Gregory 212.04 Nowak, Grzegorz 253.04 Noyes, Robert 253.02 NStED Science Team, 140.20 Nugent, P. 308.01 308.04 Nugent, Peter Nugent, P 337.13 Nugent, Peter E. 337.11, 337.26, 337.29 Nulsen, Paul 142.18 Nulsen, P. E. J.. 125.05 Nulsen, Paul E. J. 142.20 Nunez, Alejandro 242.04 NuSTAR Team, 142.42, 254.09, 254.13, 254.25 Nutzman, Philip 343.11, 415.02D Nymeyer, Sarah 402.02, 418.01, 418.02 Nysewander, M. 141.01 O'Brien, Katelyn M. 149.28 O'Connell, Julia 429.09 O'Connell, R. 152.06 O'Connell, Robert W. 312.04, 335.18, 335.19 O'Dowd. Matthew 326.07 O'Hara, Andrew 156.07 O'Neill, Sean M. 105.07 Oberg, Karin I. 339.15 Oberoi, Divya 155.02 Oda, Takeshi 308.05D Oesch, Pascal 229.05 Oey, M. S. 327.06

Ofek, Eran 157.11 Offner, Stella 258.10 Offner, Stella S. R. 258.13 Ogle, Patrick 115.04, 230.04, 335.27 Oguri, Masamune 252.21, 252.22, 347.04 Oh, Kyuseok 422.03, 430.36 Oh, Se-Heon 147.14, 328.03D Oishi, Jeffrey S. 144.18 Okamoto, Y 339.05 Okamoto, Y K. 157.03 Okazaki, Atsuo 338.17 Okazaki, Atsuo T. 339.24 Oksanen, Arto 338.14 Oleas, Gina 425.05 Olivares, Andres 157.09 Oliveira, Cristina 254.28 Oliveira, Cristina M. 254.01 Olling, Robert 144.08 Olsen, Julia K. 252.04 Olsen, Knut 337.32 Olsen, Knut A. 252.15 Olson, Roberta J. M.. 111.01 Oluseyi, Hakeem 252.13 Oluseyi, Hakeem M. 155.10, 155.11 Oman, Kris 258.06 OMEGA Explorer Science Team, 403.07 Omont, Alain 430.11 Omont, Andrew 430.28 Onaka, T 157.03 Onello, Joseph 434.37 Onken, Christopher 430.10 Oosterloo, Tom 115.04, 422.04 157.03 Ootsubo, T Oppenheimer, Ben R. 344.18, 413.05D Oran, Elaine S. 337.08 Orange, Norton B. **155.10**, 155.11 Oravetz, Daniel 153.09, 153.10 129.01 Orchiston, W. Orchiston, Wayne 146.01, 146.02, 146.03, 146.04, 146.05, 146.07, 146.08, 146.09, 146.10, 146.11, 146.12, 210.01 116.07 Ord, Stephen Ordenes, Yasna 434.16 Orellana, Mariana 339.09 Orosz, Jerome 432.14 Orosz, J. A. 103.07 Orosz, Jerome A. 140.04

Orosz, J A. 143.04 Orosz, Jerome A. 152.34, 152.36, 201.03 Orton, Glenn 257.09 Orton, Glenn S. 156.08 Osborne, Julian P. 338.14 Oskinova, Lida 144.26 Osorio, Mayra 255.15 Osten, Rachel 140.14, 254.01, 254.04 Osten, Rachel A. 242.18, 254.02, 342.07 Osterman, Steve 253.09, 401.01, 401.02 Osterman, Steven N. 254.28 Östman, Linda 434.27 Ostorero, Luisa 106.03D Ostriker, Jeremiah P. 212.04 341.02 Oswalt, T D. Oswalt, Terry D. 341.03 Ota, Kazuaki 335.13 Otsuka, Masaaki 337.22 Ott, Juergen 133.05, 147.08, 147.10, 245.09, 251.26, 413.02 Otto, Elizabeth 153.03 Overzier, Roderik 325.03 Owen, Frazer 413.02, 413.03 Owocki, Stanley 338.17 Ozel, Feryal 215.05 Paciesas, William S. 434.01 Packham, Chris 157.18 Packham, Christopher C. 157.03 Padgett, Deborah 131.01, 333.05, 333.06, 340.24 Padgett, Deborah L. 411.05 Padilla, Nelson 407.02, 407.04 Padmanabhan, Nikhil 150.05, 222.07, 249.06 Paech, K. 308.01 Paech, Kerstin 308.04 Paech, K 337.13 Paegert, M. 252.09 Paegert, Martin 334.12 Paerels, Frits 250.10 Pagano, Michael D. 153.02 Page, Kim L. 338.14 Pagnotta, Ashley 338.12, 338.13 Pagnotta, Ashley S. 338.14 Pain, R. 308.01 Pain, Reynald 308.04 Pain, R 337.13 Paiton, D. 242.06 PALFA Consortium, 336.12

Palliyaguru, Nipuni 139.02 Palma, Norman 408.02 Palomar Transient Factory, 220.01 Pan, Danny 204.03D Pan, Kuo-Chuan 337.05 Pan, Xiaopei 425.01 Pan-STARRS-1 Science Consortium, 435.02 Panagia, Nino 258.27, 308.05D Panagoulia, Electra 142.18 Pancoast, Anna 430.18 Pandian, Jagadheep D. 113.01 427.05D Pang, Xiaoying Pannuti, Thomas 256.33 Papa, Maria A. 234.01 Papovich, Casey 149.19, 255.14, 407.09 Papp, Istvan 253.02 Paradis, Deborah 112.08 Parashare, Chaitali 432.06 Parejko, John K. 249.06 Parent, Damien 215.02 Paresce, Francesco 258.27 Park, Alex 252.10 Park, Byeong-Gon 433.08 Park, Geumsook 251.29 Park, Hong Soo 152.04 Park, Kwijoing 433.08 Park, Pulun 430.21 Park, Samuel 144.25 Park, Sangwook 256.28 Parker, Angela 245.07 Parker, Alex 306.02D Parry, Ian 413.05D Parsons, Aaron 432.06 Participants in LAMOST, US (PLUS), 334.13 Pasachoff, Jay M. **111.01**, 306.05 Pascucci, Ilaria 254.01 335.34, 335.35, 427.05D Pasquali, Anna Passy, Jean-Claude 144.18 Patat. Ferdinando 434.30 Patel, Harsit 430.29 Patel, Nimesh 434.44 Patel, Rahul 253.03 Patel, S. K. 141.01 Patel, Shannon 233.06 Patikkal, Anand 247.10 Patnaude, Daniel 130.05

Patrick, Phillip A. 142.09 Patterson, Joseph 434.09 Patterson, Maria 246.22 Patterson, Richard J. 242.25, 424.05 Paul, Jacques 425.04 Pauly, Tyler 251.19 Paust, Nathaniel 152.13, 152.14 Pavel, Michael 241.15 Pavel, Mike 250.05 Pavel, Michael D. 251.03, 251.04 Pavlidou, Vasiliki 142.01, 142.02, 231.01 Pavlovsky, Cheryl M. 254.39 Paxton, Bill 432.26 Payan, Juan C. 144.12 157.09 Payne, Ifan Payne, Matthew J. 343.20 Peacock, Mark 409.04D Peale, Robert 202.01 PEARS team, 335.45 Pearson, John C. 210.01, 217.07 Pearson, Timothy J. 142.01, 142.02 Pearson, Tim J. 229.02D Pecontal. E. 308.01 Pecontal, Emmanuel 308.04 Pecontal, E 337.13 Pedretti, Ettore 257.03 Peek, Josh 241.01 Peek, Joshua 241.02, 241.04 Peek, Joshua E. G. 241.03, 241.06, 251.29 Pehrson, Steve 430.04 Peimbert, Antonio 434.35 Pellegrini, Paulo 430.04 Pellerin, Anne 311.05, 342.06 Peltier, Abigail 340.28 Pelton, Russell S. 254.12 Pena-Guerrero, Maria A. 434.35 Penarrubia, Jorge 152.28 Penev, Kaloyan 253.01, 253.02, 402.06 Peng, Eric 312.03 Peng, Eric W. 152.03 242.07 Penny, Laura Penprase, Bryan E. 433.11, 434.30 Penteado, Paulo 435.03 Penton, Steve 254.03 Penton, Steven 345.11 Penton, Steve 432.03

Penton, Steven V. 254.28 242.29, 252.15, 334.12 Pepper, Joshua Pequette, Naomi 335.11 Percival, J. W. 251.07 Percival, Will 222.07, 249.06 Percival, Will J. 150.05 Percy, John 420.02 Pereira, R. 308.01 Pereira, Rui 308.04 Pereira, R 337.13 Perez, Laura 419.03 Perez, Laura M. 419.04 Pérez-Hoyos, Santiago 156.08 Perillat, Phil 433.13 Perley, Daniel A. 108.02D Perley, Rick A. 413.01 Perlmutter, S. 249.09 Perlmutter, S 249.10 Perlmutter, Saul 254.12 Perlmutter, S. 308.01 Perlmutter, Saul 308.04, 308.05D Perlmutter, S 337.13 Peroux, Celine 426.04 340.19, 340.29 Perrin, M. Perrin, Marshall D. 339.04 Perry, Thomas M. 142.31 Person, Michael J. 306.05 Persson, S. E. 311.04 Pesenson, M. 252.09 Pessev, Peter 434.16 Pestalozzi, Michele 202.02 Petach, Helen 142.43, 248.12 Peters, Charee 337.27 Peterson, Bradley M. 430.07 Peterson, Bradley W. 335.27 Peterson, Dawn 258.15 Peterson, Dawn E. 258.16 Peterson, J. R. 149.15 Peterson, John R. 151.01, 213.01, 252.07, 252.08, 252.21 Peterson, J. R. 252.24 Peterson, John R. 252.25 Peterson, Steffanie 142.39 Peterson, William M. 105.05 Petre, R. 256.12, 340.19, 340.29 Petro, Larry 254.36, 254.37, 254.38 Petro, Larry D. 226.03, 254.40

Pettini, Max 326.05 Petty, Sara 333.13, 333.14, 333.15 Petty, Sara M. 333.17 Pety, Jerome 246.11 Pevunova, O. 344.08 Pewett, Tiffany 339.21 Pfrommer, Christoph 109.03D Phaneuf, Ronald A. 256.05 PHAT collaboration, 207.02, 207.03, 222.01 Phelan, Scott 258.22 Phifer, Kim A. 241.13 Philbrick, C. R. 402.03 Philip, A. G. D.. 340.11 Phillips, Chris 256.27 Phillips, Mark M. 337.11, 434.30 Piche, Francois 157.17 Pick, Monique 146.08 Pickett, Megan K. 429.02 Pieri, Matthew 345.11 Pierpaoli, Elena 430.39 Pierre, Marguerite 149.19 Pihlstrom, Ylva 246.07, 413.03 Piirola, Vilppu 434.34 Pike, Rosemary E. 251.23 Pilachowski, Catherine A. 152.39, 346.05, 406.01 348.01 Pilacik, Faith Pilyavsky, Genady 220.03 Pindor, Bart 116.07 Pineda, Jorge 251.26 Pingel, Nick 241.02 Pingel, Nickolas 241.05 Pingel, Nickolas M. 241.03, 241.04 Pingel, N. M. 251.07 Pinnick, April 241.15, 250.05 Pinnick, April F. 251.03, 251.04 Pinsonneault, Marc 334.12, 436.03 Pinsonneault, Marc H. 343.23, 434.20 Piper, Margaret (Peggy) 248.10 Piper, Peggy 342.03 Pipher, Judy 258.19, 258.21 Pipher, Judith L. 343.14 Pipino, Antonio 149.09, 241.12, 430.39 Pirzkal, Nor 254.36 Pirzkal, Norbert 254.38 Pirzkal, Nor 254.39, 335.19 Pirzkal, Norbert 335.45, 407.03

Pisano, D.J. 258.29)
Piso, Ana-Maria 343.24	ŀ
Pitman, Karly M.	112.06
Pizagno, James 252.07	
Pizagno, Jim 252.08	3
Pizagno, James 252.18	
Pizagno, Jim 252.21	, 252.25
Pizagno, James 430.06	
Plambeck, D. 323.06	5
Planck Collaboration 201	1a, P243.01
Planck Collaboration 201	1aa, P243.27
Planck Collaboration 201	1b, P243.02
Planck Collaboration 201	1c, P243.03
Planck Collaboration 201	1d, P243.04
Planck Collaboration 201	1e, P243.05
Planck Collaboration 201	l1f, P243.06
Planck Collaboration 201	1g, P243.07
Planck Collaboration 201	1h, P243.08
Planck Collaboration 201	1i, P243.09
Planck Collaboration 201	1j, P243.10
Planck Collaboration 201	1k, P243.11
Planck Collaboration 201	11, P243.12
Planck Collaboration 201	1m, P243.13
Planck Collaboration 201	1n, P243.14
Planck Collaboration 201	10, P243.15
Planck Collaboration 201	1p, P243.16
Planck Collaboration 201	1q, P243.17
Planck Collaboration 201	1r, P243.18
Planck Collaboration 201	1s, P243.19
Planck Collaboration 201	1t, P243.20
Planck Collaboration 201	1u, P243.21
Planck Collaboration 201	1v, P243.22
Planck Collaboration 201	1w, P243.23
Planck Collaboration 201	1x, P243.24
Planck Collaboration 201	1y, P243.25
Planck Collaboration 201	1z, P243.26
Plavchan, Peter 220.05	, 340.21, 340.32
Player, Virginia 248.1	4
Plesko, Catherine	156.09
Pletsch, Holger J. 234.01	
Plotkin, Richard M.	230.01, 230.02, 430.13
Plucinsky, Paul P.	246.10
Plume, Rene 241.02	
Pluzhnik, Eugene	254.06
Pober, Jonathan 432.06	
Podsiadlowski, Philipp	432.26

Poglitsch, Albrecht 202.08 Pohl, Brian 152.11 Points, Sean 147.02, 256.29, 345.10 Polisensky, Emil 413.03 Pollaco, Don 418.02 Pollmann, Ernst 339.24 Poludnenko, Alexei Y. 337.08 Pompea, Steve 209.06 Pompea, Stephen M. 248.03 Pooley, David 152.31 Pooley, David A. 403.05 Popescu, Bogdan 152.01, **427.01D** Porritt, Christopher R. 144.13 Portegies Zwart, Simon F. 153.01 Postman, Marc 227.06 Postman, M. 249.09 Postman, Marc 308.05D Poteet, Charles 255.15 Potter, Toby M. 256.27 Povich, Matthew S. 409.05 Powell, W. L. 247.09 Poyneer, Lisa 339.04 Poznanski, Dovi 337.21, 337.26 Prada, Francisco 150.05, 222.07, 249.06 Pradhan, Anil K. 434.40, 436.03 Prather, Edward E. 247.01, 247.02, 247.03, 247.04, 247.05, 247.06, 247.08 Prather, Ed E. 252.04 Prato, Lisa 253.13, 253.14, 340.18 Prato, L 343.01 Prato, Lisa A. 145.09, 340.23 Preece, Robert 434.01 Preston, George 153.13, 154.03 Preston, George W. 434.30 Preston, Sandra 158.02 Prestwich, Andrea H. 144.23 Preuss, Lauren 155.10, 155.11 Price, Aaron 158.11, 158.12 Price, S 340.13 Price, Stephan D. 342.01 Prieto, J L. 334.17 Primack, Joel R. 211.04 Prince, Tom 225.04 Prince, Thomas A. 347.07 Principe, Dave 340.30 Pritchard, Jonathan 107.09 Pritchard, Jonathan R. 107.03

Pritchard, Tyler A. 337.25 Pritchet, Chris J. 308.06 Pritchet, Christopher J. 337.11 Pritzl, Barton J. 311.03D 234.01 Prix, Reinhard Probst, Ronald G. 147.02 Prochaska, Jason X. 132.04D Prochaska, J X. 345.09 Prochaska, T. M. 433.12 Prodanovic, Tijana 231.01 Proffitt, Charles 254.01, 254.04 Proffitt, Charles R. 254.02 Proga, Daniel 142.48 Protopapas, Pavlos 116.01, 435.02, 435.06 Provencal, Judith L. 341.05 Prsa, Andrej 140.04, 140.10, 144.01, 144.02, 144.03, 144.04, 252.15, 342.02 Ptak, A. 114.07, 252.09 Ptak, Andrew 252.16 PTF Collaboration, 220.05 Puatua, Wendy 344.14 Puckett, Tim 337.18 Puerari, Ivanio 246.15 Pueyo, Laurent 254.31, 344.18, 413.05D Pugh, Bryan 342.11 Pulliam, Robin 331.01 Puravankara, Manoj 255.04, 255.15 Putman, Mary 241.02, 241.04, 241.06 Putman, Mary E. 241.01, 241.03 Pyle, Tim 420.03 Quarles, Billy 415.05 Quataert, Eliot 303.03D Quijada, Manuel 254.16 Quimby, Robert 337.30 Quimby, Robert M. 434.30 Quinlan, Frank 253.09 401.01 Quinlan, Franklin Quinlan, Frank 401.02 Quinn, James P. 343.10 Quinn, Sean 142.19 Quinn, Samuel 201.02 Quinn, S. A. 103.07 Quinn, Tom 128.01D Quinn, Thomas 142.46 Quinn, Tom 147.09, 216.02D Quinn, Thomas 322.06, 328.05 Quinn, Thomas R. 241.11, 415.01

Quint, Amanda 334.08 140.05 Quintana, Elisa Quintero, Luis 433.13 Quirk, Trevor S. 142.09 Quitzow-James, Ryan 432.27 Rabinowitz, D. 308.01 Rabinowitz, David 308.04 Rabinowitz, D 337.13 Rabinowitz, David 433.18 Rabinowitz, David L. 126.04 Rabus, Markus 253.02 Racusin, Judith 141.07 Radburn-Smith, David J. 417.01 Raddick, Jordan 247.05 Raddick, M J. 252.04 Radigan, Jacqueline 226.01 Rafelski, Marc 309.03D Ragozzine, Darrin 103.05 Ragozzine, Darin 140.13, 201.01, 252.10, 343.04, 418.02, 435.02 Rahman, Mubdi 251.14, 427.04 Rahman, Nurur 417.04 Rahman, Shahinur 426.02D Rahman, Shahin 426.04 Rajan, Abhijith 254.36, 254.37, 254.39 Rajan, Ahbijith 254.41 Rakoczy, Lila 111.03 Ramaprakash, A. N. 157.11 Ramien, Natalie 248.14 Ramírez, Solange V. 220.05 Ramirez-Ruiz, Enrico 132.04D, 152.31 Ramos, Beatriz 150.05 253.09, 401.01, 401.02 Ramsey, Larry Ramseyer, Elizabeth 142.43, 248.12 Ramsrud, Nic 157.10 Rand, Richard 246.21, 246.22 Rand, Richard J. 246.20, 246.23 Randall, Emily 256.29 Randall, Scott W. 148.01 Rankin, Joanna 336.09, 336.10 Rankin, Joanna M. 139.07, 336.11 Ransom, Scott 234.05, 336.05 Ransom, Scott M. 139.05, 139.06, 234.01 Rao, Sandhya 345.05 Rapchun, David A. 157.07 Rapoport, Sharon 306.05 Rappaport, Saul 432.26

Rasio, Fred 415.07 Raskin, Cody 337.20, 341.09 Rasmussen, Andrew P. 252.07, 252.08, 252.21, 252.25 Rasmussen, Jesper 149.13 Ratcliffe, D. M. 252.04 Ratti, Eva M. 144.24 Rauscher, Bernie 254.27 Rauscher, Bernard J. 254.12, 254.18 Ravindranath, Swara 231.06 Rawle, Tim 430.38 Ray, Paul 413.03 Ray, Paul S. 336.07 Raymond, John C. 256.21, 256.22 Raymond, Sean N. 343.22 257.09 Rayner, John Razeghi, Manijeh 425.06 Razzaque, S 108.06 **RCS** Collaboration, 227.04D Rea, Nanda 144.24 Rea, Robert D. 338.14 Read, James W. 142.31 Readhead, Anthony 142.38 Readhead, Anthony C. S. 142.01, 142.02, 142.44 Readhead, Anthony C. S.. 229.02D Rebull, Luisa 131.01, 340.21, 340.24, 340.32, 346.07, 406.01 Rebull, Luisa M. 144.22, 220.05, 248.11, 248.13, 258.04, 340.08 Rebusco, Paola 343.24 RECONS, 242.16, 242.26 Red, Eddie C. 256.05 Redfield, Seth 251.10, 343.05, 343.06 Redman, Stephen 253.09, 401.01, 401.02 Redman, Stephen L. 401.04D Reed, Mike 334.08 Reese, D. T. 251.07 Reese, Erik D. 227.05D Reeves, Rodrigo 142.01, 142.02, 142.44 Regan, Michael 254.27 Regan, Michael W. 207.06, 246.12 Regencia, Paul 252.13 Reichart, D. E. 141.01 Reid, I. Neill 253.10 Reid, I N. 242.04 Reid, Mark 142.57, 323.06 Reid, Neill 242.18 Reines, Amy E. 128.02D Reis, Rubens C. 404.02

Reitzel, David 152.20, 152.21, 152.22, 152.27 Reitzel, David B. 153.12 Remijan, Anthony 331.01 Remillard, R. A. 143.04 Remillard, Ronald A. 404.02 Remmen, Grant N. 151.04 Renbarger, Tom 249.02, 249.03 Rengstorf, Adam W. 346.11, 346.12 **RESOLVE** Team, 334.14 Ressler, Michael E. 433.06 337.32 Rest, Armin Restaino, S. R. 242.06 Rettig, Terrence 434.21 Reuter, Cassie 434.52 430.38 Rex, Marie Reyes, Reinabelle 430.06 Reyle, Celine 242.29 Reynolds, Christopher 142.29 Reynolds, Christopher S. 105.07, 106.02D, 125.02 Reynolds, R. J. 251.07 Reynolds, R J. 251.09 Reynolds, S. P. 256.12 Reynolds, Stephen P. 256.13, 256.21, 256.22 Rheault, Jean-Philippe 433.09 Rhee, Joseph H. 322.05 Rho, Jeonghee 256.21 Rhoads, James 335.17, 335.19, 407.03 Rhoads, James E. 335.43, 335.45 Rhode, Katherine L. 409.02D, 409.03 Rhodes, Jason 109.05 249.09 Rhodes, J. Ribas, Ignasi 113.07, 140.18, 156.02 Ribaudo, Joseph 345.09 Ribeiro, J. 257.04 307.05D, 413.05D Rice, Emily Rice, Steve 254.16 Rice, Thomas 340.16 Rich, Jeffrey 114.05D Rich. Mike 241.12, 333.17 Rich, R. Mike 149.09 Rich, R. Michael 152.20 Rich, R. M. 152.21, 152.22, 152.23, 152.24 Rich, R M. 152.25 Rich, R. M. 152.26 Rich, Robert M. 152.27 Rich, R M. 153.12

Rich, R. M. 226.06 Richards, Emily 241.07 Richards, Gordon 230.05 Richards, Gordon T. 230.01 Richards, G. T. 252.17 Richards, Gordon T. 347.04 Richards, Joseph 142.01 Richards, Joseph L. 142.02, 142.44 Richards, Thomas 338.14 Richardson, Logan 432.24 Richardson, Mark 335.43, 341.09 Richardson, Mark L. 116.02 Richardson, Noel 154.11 Richardson, Noel D. 406.03 Richardson, Whitney 158.05 Richer, Harvey 152.21, 152.22, 152.23 Richer, H. 152.24 Richer, Harvey 152.25, 152.26, 152.27 Richer, Harvey B. 152.20 Richer, Michael 157.07 Richert, Alex 340.22 Richmond, Michael 340.30 Richmond, Michael W. 226.03 Richstone, Douglas 422.05 Richstone, Douglas O. 422.06 Richter, M 157.03 Richter, Phillip 345.04 Rickard, Lee 413.03 Ricker, Paul M. 109.04D Ricker, Paul 149.04 Ricker, Paul M. 147.01, 213.03D, 337.05 Ricketts, Paul 157.10 Ricotti, Massimo 424.02D Riddle, Reed 433.14 Riddle, Reed L. 157.11 Ridgway, Stephen 415.04 Ridgway, Stephen T. 242.03, 252.10, 343.07 Riechers, Dominik 335.21, 430.11, 430.23 Riedel, Adric R. 242.05, 242.16 Rieke, George 339.01, 339.08, 434.45 Rieke, George H. 433.06 Rieke, Marcia 255.14 Ries, Paul 158.05 Riess, Adam 227.06, 254.41 Riess, Adam G. 254.12 Rigby, Jane 145.03, 311.04

Rigby, Jane R. 114.04, 255.14 Rimmer, Paul 217.07 Rinehart, Stephen 157.08 Rines, Kenneth 149.12 Rines, Kenneth J. 109.01 Ripoche, P. 249.09 Ripoche, P 249.10 Ripoche, Pascal 308.05D Risaliti, Guido 142.21, 142.42 Ritchey, Adam M. 256.23 Rivera, Emy M. 434.33 Rivera, Jesus 336.12 Rivers, Elizabeth 430.17 **Rivinius**, Thomas 339.24 Rix, Hans-Walter 246.11, 254.27 Rix, Hans W. 246.05 Rizzi, Luca 328.02D Robberto, Massimo 254.20 202.05, 255.02, 406.01 Roberge, Aki Roberge, Wayne G. 339.07 Roberge, Wayne G. 251.01, 251.03 Roberson, April 140.18 Roberts, D. 323.06 323.07 Roberts, Doug Roberts, George 338.14 Roberts, Jennifer 340.04 Roberts, Jessica 429.03 Roberts, Lewis 344.18, 413.05D Roberts, Mallory 105.06 Roberts, T. P. 114.07 Roberts, Timothy P. 325.07 Robertson, Amy 258.26, 331.01 Robertson, Jordan 144.01, 144.02, 144.03 Robertson, Jordan A. 144.04 Robertson, Paul 149.20 Robertson, Thomas H. 346.01, 348.05 Robin, Annie C. 241.12 Robins, Derek 142.56 Robinson, Frederick D. 157.07 Robinson, Paul E. 247.09 Robinson, Rebecca 342.08 Robinson, Tyler D. 349.04 Robitaille, Thomas 145.03, 241.16 Rochau, G A. 433.24 Rockefeller, Gabriel R. 423.05 Rodi, James C. 434.01

Rodriguez, David R. 131.06D Rodriguez, Luis F. 434.44, 434.46 Rodriguez, Samelys 313.05 Rodriguez Hidalgo, Paola 142.30, 345.04, 345.07 Rodriguez-Hidalgo, Paola 345.05 Roe, Natalie A. 433.02 Roederer, Ian U. 154.03, 242.12 Roelofsen Moody, Theresa 209.07 Roesler, F L. 251.09 Roettenbacher, Rachael M. 342.05 Rogers, Anthony 344.07 Rogers, Alan E. E.. 248.06 Rogers, Alan E. E. 346.10 Rogers, Jessamy 251.18 Rohr, Matthew 139.08 Rojo, Patricio 126.04 Romani, Roger 142.44 Romani, Roger W. 142.01, 142.02, 229.02D, 336.02, 336.04 Romaniello, Martino 434.19 Romeo, Robert 413.06 Romero, Charles 158.05 Romero, Gisela A. 339.09 Romero, Joey 248.10, 342.03 425.02 Roming, Peter Roming, P. W. A. 337.25 156.01 Romney, Jon Ron Samec, Evan Figg, Bruce Oliver, Astronomy Prog, ram, Bob Jones University 144.14 Rood, Robert T. 132.01, 132.02, 132.03 Rood, R. T. 251.02 Roodman, Aaron J. 239.03, 433.02 256.31 Roper, Quentin Rosario, David J. 142.58, 211.04, 310.05, 310.06 249.09 Rosati, P. Rosati, Piero 308.05D Rosche, Emily 144.03 Rose, James A. 211.02D Rosen, Rachel 145.06, 209.08 Rosenberg, Duane 251.13 Rosenberg, Jessica L. 345.12 Rosenfield, Philip 328.01 Rosenthal, Casey 420.03, 420.04 251.02 Roshi, D. A. Rosignolo, Rebecca 248.10, 342.03 Rosing, Wayne 306.05 Roskar, Rok 241.11 Roskar, R. 252.14

Roskar, Rok 322.06, 417.01 Rosner, Robert 308.03 Rosolowsky, Erik 411.03D Ross, Ashley 150.05, 222.07 Ross, Nic 150.05 Ross, Nicholas 222.06 Ross, Nic 222.07 Ross, Nathaniel 335.13 Ross, Nicholas P. 222.05 Rostem, Karwan 313.05 Rosvick, Joanne 158.08 Rothschild, Richard 430.17 Rottgering, Huub 142.40 Roustazadeh, Parisa 212.05D Rowan-Robinson, Michael 430.29 Rowe, Jason 103.04, 140.05, 201.02, 429.08 Rowe, Jason F. 103.01, 140.03, 140.07, 429.03 Roy, Amit 342.08 Roy, Arpita 401.01 Rozo, Eduardo 213.06 Rubin, D. 249.09 Rubin, David 249.10, 308.05D Rubin, Kate H. 335.16 Rubin, Vera 258.32 Rubio, Monica 147.02 Rucinski, Slavek 140.10 Rucker, Michael 140.04 Rudd, Robert 253.12 Rudio, Olivia 248.10, 342.03 Rudnick, Grerory 149.19 Rudnick, Gregory 213.05, 255.14, 335.14 145.07 Rudolph, Alexander 340.07 Rudolph, Alex Rudolph, Alexander L. 247.03, 247.07, 247.09 Rudy, Alex R. 433.14 Ruhlen, Laurel 404.03 Runge, K. 308.01 Runge, Karl 308.04 Runge, K 337.13 Runnoe, Jessie 142.04 Rupen, Michael P. 157.02, 413.01 Rupert, Justin 142.09 Rupke, David 245.05 Rupke, David S. N. 335.41 Russell, Christopher 338.17 Russell, Ray 257.09

Ruth, Richard 343.18 Rutherford, John 256.16, 434.31 Rutkowski, Michael J. 142.59, 335.18 Ruzhitskaya, Lanika 405.06, 405.07 Ryan, Russell E. 142.40 Ryan Jr., Russell E. 335.18 158.06 Ryer, H. Rykoff, Eli 213.06 Rykoff, E. 249.09 Rykoff, E 249.10 Ryon, Jenna 148.06 S4G Team, 207.05, 207.06, 207.07, 207.08, 246.01 Saar, Steve 155.05 Sabbi, Elena 254.39 Saburova, Anna 335.49 Sackett, Penny 253.02 Sadler, Philip M. 209.03, 405.01 Sadler, Suzanna M. 337.14 SAFIRES Team, 334.09 SAGE Team, 258.28 SAGE-LMC Spitzer Legacy Team, 251.27 SAGE-SMC Spitzer Legacy Team, 154.04, 251.27 Saha, Abi 153.10 Saha, Abhijit 246.17, 252.15 Sahai, Raghvendra 113.02 Sahnow, Dave 254.01 Sahnow, David 254.03 Sahnow, David J. 254.02, 254.12 Sahu, Kailash C. 342.07 Saintonge, Amelie 149.06 Saito, Shun 222.07 Saitoh, Takayuki R. 335.48 Sakai, Shoko 147.11 Sakai, S. 147.12 Sakamoto, Taka 108.04 Sakamoto, Takanori 336.08 Sakari, Charli 434.48 Saken, Jon M. 242.08 Sako, Masao 213.01, 434.27 Sakon, I 157.03 Salim, Samir 335.33 Salimbeni, Sara 430.35 257.03 Sallave-Goldfinger, PJ Sallum, Stephanie 142.37 Salois, Amee 335.29 Salter, Chris 142.62, 434.33

Salter, Christopher J. 245.10 Salvato, Mara 335.37, 430.23 Salvesen, Greg 149.14 Salviander, Sarah 142.58 Salway, Elora 144.13 Salyk, Colette 339.06 Salzer, John J. 147.16, 409.02D Samarasingha, Iranga 346.06 Samarasingha, Upul Iranga 157.10 Sambruna, Rita M. 125.02 Samec, Ronald G. 144.06 254.28 Sami, Niemi Samoska, Lorene A. 433.10 Samuel, Matthew V. 157.07 Sánchez-Lavega, Agustin 156.08 Sand, David J. 308.06 Sanders, Dave 326.02D Sanders, David 335.30 Sanders, David B. 326.01, 335.38 Sanders, J. S. 149.15 Sanders, Steven J. 144.07 Sanderson, Robyn E. 242.19 Sandford, Cato P. 252.22 Sandhu, Jagmit 253.11 Sandquist, Eric L. 152.34, 152.36 Sandstrom, Karin M. 202.07 Sankrit, Ravi 256.22 343.12 Santapaga, Thomas Santo Pietro, Vince 248.09 Santoro, Fernando 157.09 Santoro, Fernando G. 157.14 Santos, Mario G. 249.04 340.22 Santos, Nuno Santos Jr., João F. C.. 312.02D Sapozhnikov, Leonid 433.02 Sarajedini, Ata 242.25 Sarajedini, A. 252.14 Sarajedini, Ata 252.15, 342.16 Saran, Deepali V. 319.07 Sarazin, Craig L. 227.05D Sargent, Benjamin A. 232.01 Sari, Pal 253.02 Sarid, Gal 156.04 Sarma, Anuj 332.01 Sarrazine, Angela R. 248.05 Sarty, Gordon 158.08

Sarzi, Marc 106.07, 422.03, 422.04, 430.36 Sasselov, Dimitar 253.02 Sato, Kosuke 434.31 Satterfield, Joseph 256.15 337.32 Sauer, Daniel Saul, Destry 241.01, 241.02, 241.04, 241.06 Saul, Destry R. 241.03 Saumon, Didier 343.14 Saurage, Gabrelle 257.05 Sauter, Jefferson 129.01 Sauter, Juergen 416.03D Savage, Blair 345.11 Savage, Blair D. 345.12 Savransky, Dmitry 318.02D Sayers, Conor C. 341.01 Sayers, Jack 413.04D Saylor, Dicy Ann E. 156.11 Sayres, Conor 344.09 Saz Parkinson, Pablo 336.06 Scalzo, R. 308.01 Scalzo, Richard 308.04 337.13 Scalzo, R Scannapieco, Evan 116.02, 337.20, 341.09, 433.23 252.09 Scargle, J. Scargle, Jeffrey D. 108.03 407.07, 407.08 Scarlata, Claudia Scarpine, Vic 239.04 Schade, David 344.03 Schade, Patricia 108.04 Schaefer, Bradley E. 338.14 Schaefer, Gail 242.03, 242.23, 257.03, 415.04 Schaefer, Gail H. 406.03 Schaefer, Laura 402.01 Schalk, Terry 239.03 Schanne, L. 257.04 Schaub, Samuel C. 256.11 Schawinski, Kevin 106.04, 142.08, 142.50, 326.01, 335.23, 422.03, 430.36 Schechter, P L. 143.04 Schechter. Paul L. 157.06 Schiavon, Ricardo P. 335.15 Schiminovich, David 326.07, 426.04 Schindhelm, Eric 339.13, 340.33 Schinnerer, Eva 233.04, 246.11, 430.23 Schisano, Eugenio 202.02 Schlaerth, James A. 413.04D Schlafly, Eddie 434.42

Schlaufman, Kevin 323.02D Schlawin, Everett 343.02 Schlegel, David 222.07 Schlegel, David J. 150.05, 222.06 Schlegel, D. J. 249.09 Schlegel, David J. 308.05D Schlegel, Eric 256.33 Schlegel, Eric M. 256.18, 337.35, 338.02, 338.12, 338.13, 338.14 Schlieder, Joshua E. 307.05D Schlingman, Wayne 258.26 Schlingman, Wayne M. 247.02, 411.03D, 431.01 Schmalzl, M 202.03 Schmelz, Joan T. 319.03 Schmid-Burgk, Johannes 434.44 Schmidt, Andrea 234.06 Schmidt, Andrea C. 336.01 Schmidt, Brian 253.02, 403.04 Schmidt, Deborah 215.01, 336.09 Schmidt, Luke M. 157.14 Schmidt, Sarah 257.05 Schmidt, Sandra 319.01 Schmidt, Sarah 434.11 Schmidt, Sarah J. 226.05D, 242.18 Schmidt, Sam J. 335.32 Schmitt, Henrique 142.13, 413.03 Schmitt, Henrique R. 142.14, 142.15, 144.16 Schmitt, H. R. 242.06 Schmitt, Joseph 258.30 Schmitz, Marion 344.08 Schmutz, Werner 338.19 Schnee, Scott 411.06 425.02 Schneider, Don Schneider, Donald P. 142.40, 212.07, 222.06, 230.01, 230.02 Schneider, D. P. 252.17 Schneider, Glenn 142.40, 339.02 Schneider, G. 340.19, 340.29 Schneider, Jeff 153.04 Schneider, Michael 334.16 Schneider, N 340.13 Schoenwald, Justin 157.04 Schombert, James 430.26 Schonfeld, Sam 155.05 Schreiber, Matthias R. 339.09 Schruba, Andreas 133.04D, 246.14 Schuler, Simon 242.14 Schuler, Simon C. 242.01

Schuller, Frederic 113.01 Schultz, K. 239.04 Schultz, Kasey 244.01 Schulz, Bernard 230.04 Schulz, Norbert S. 254.11 Schumacher, German 239.03, 252.02 Schuster, Karl 246.11 Schwadron, Nathan 434.34 Schwalm, Mark 254.26 Schwarz, Kamber 258.26 Schwarz, Kamber R. 339.16 Schweizer, Francois 152.08 Scoccimarro, Roman 249.07, 249.08 Scott, Douglas 432.07 Scott, Erin L. 142.09 Scott, Jennifer 345.08 Scott, Kimberly S. 245.13 Scott, L. 239.04 Scott, Nicholas 148.08, 422.04 Scoville, Nicolas 246.11 Scoville, Nick 430.23 Scowcroft, Victoria 311.04 SDSS-II Supernova Survey, 434.27 103.08, 220.04, 302.07, 343.24, 349.04, 402.08, 418.01 Seager, Sara Seale, Jonathan 258.28 Seale, Jonathan P. 133.05 Sebag, Jacques 157.05, 252.02, 252.05 Sebald, David A. 149.08 Secrest, Nathan 306.05 Seebode, Sally 257.08, 346.09 SEEDS collaboration, 429.10 SEEDS Team, 339.05 Segally, William B. 346.11 Segura-Cox, Dominique 340.13 Sehgal, Aneesh 248.10, 342.03 Seibert, Mark 148.06, 311.04 Seigar, Marc 246.08 Seigar, Marc S. 246.09, 246.15 Selic, Tiffany 340.08 Selina, Rob 157.09 Sellgren, Kris 145.04 Sembach, Ken 335.09 Sengupta, Pinaki 234.06 Seon, Kwang-il 251.17 Seon, Kwang Il 251.24 Sepinsky, Jeremy F. 105.04, 144.15

Serra, Paolo 249.04, 422.04 Servillat, Mathieu 201.07, 432.25, 434.08 Sesar, Branimir 241.09, 252.13, 424.01, 430.16 Seth, Anil 148.04, 207.02, 207.03 Seth, A. 233.05, 252.17 Seth, Anil C. 106.06 Severson, Scott A. 433.14 Sewilo, Marta 258.28 SGAS Collaboration, 227.04D Shabram, Megan 402.04 Shackleford, Bryce 147.12 Shackleford, Bryce R. 147.11 Shadmehri, Mohsen 258.01 Shahmoradi, Amir 141.04, 249.05 Shaklan, Stuart 253.12, 254.29 Shankland, Paul D. 343.25 Shannon, Andrew B. 434.22 Shannon, Ryan 139.04 Shao, Michael 253.11, 425.01 Shao, M. 429.09 Shapiro, Kristen 425.05 Shapley, Alice E. 211.05, 245.12, 325.04, 335.06, 335.42, 407.05, 430.15 Shaposhnikov, Nikolai 434.01 Shapovalov, Dmytro 417.07 Shara, Mike 152.20 Shara, Michael 152.21 Shara, Mike 152.22 Shara, M. 152.24 Shara, Michael 152.26, 152.27 Shara, M. M. 152.23 Shara, Michael M. 152.25, 226.05D Sharon, Keren 114.04, 213.02D, 227.04D Sharp, Elmer 313.05 Shaw, John 253.11 342.10 Shaw, Kristie Shaw, Michael S. 142.01, 142.02 Shaw, T. 239.04 Shaya, Ed 144.08 Shaya, Edward J. 328.02D Shcherbakov, Roman 303.02D Shectman, Stephen 153.13, 154.03 Shectman, S. A. 433.12 Sheets, John 113.07, 156.02 Sheldon, Erin 213.06 Shemmer, Ohad 230.01, 230.02 Shemmer, O. 252.17

Shemmer, Ohad 421.04 Shen, Juntai 241.12 Shen, Yue 230.05 Shenoy, Sachin S. 131.02D Sherry, Leanne 255.07 Sherry, William 242.10 Sheth, Kartik 207.06, 246.01, 335.36 Shetrone, Matthew 242.12, 327.05 Shetrone, Matthew D. 152.34, 152.36 Shiao, Bernie 140.16, 344.07 Shields, Aomawa 349.04 Shields, Gregory A. 142.58, 149.20, 310.05, 310.06 Shields, Joseph C. 106.07, 142.30, 246.05, 422.03 Shih, I C. 409.03 Shim, Hyunjin 430.33 Shin, Min-Su 245.12 Shipley, Heath V. 338.02 Shipman, Harry 341.05 Shirley, Yancy L. 258.26, 411.03D Shitanishi, J. 251.02 Shivvers, Isaac S. 141.03 Shkolnik, Evgenya L. 253.10 Shmakova, Marina 252.07, 252.08, 252.21, 252.25 Shmakova, Satya M. 252.18 Shoemaker, Deirdre 432.15 Sholl, Michael 433.03, 433.04 Short, Ian 158.08 Showman, Adam 402.08 Shporer, Avi 126.01D, 126.02, 220.01 Shrader, Chris R. 144.28 Shu, Xin Wen 326.08 Shull, J. M. 142.36, 217.06, 256.20, 345.11, 345.12 Shupe, David L. 255.05 Siana, Brian 335.20, 407.07, 407.08 Siana, Brian D. 407.05 Siegel, Michael H. 250.07 Siegel, Seth 213.06, 413.04D Siemens, Xavier 139.08, 234.01, 234.05, 336.12 Siemiginowska, Aneta 142.33 Siemion, Andrew 240.03, 240.06 Sierra, Amber 246.15 Sieth, Matthew 433.10 Sievers, Jonathan 109.03D Sievers, Jonathan L. 313.03 Sigman, Elliot 413.03 Sigurdsson, Steinn 349.03

Silic, Tiffany 346.07 Silk, Joseph 312.04 Silva, David 252.03, 252.15 Silva Villa, Esteban 327.03D Silverman, Jeffrey 324.05 Silverman, J. M. 337.21 Silverman, Jeffrey M. 337.26 Silvia, Devin W. 256.20 Simcoe, Robert A. 343.14 Simha, Vimal 421.06D Simmerer, Jennifer A. 153.14 Simmons, Sloane K. 153.13 Simon, J. 252.14 Simon, Jacob B. 322.01 Simon, Joshua D. 147.04, 434.30 Simon, Leah 326.05 Simon, Michal 307.05D Simon, R 340.13 Simon, Theodore 434.21 Simon-Miller, Amy A. 156.08 Simonia, I 129.01 Simonia, Irakli 146.11 Simpson, Janet P. 113.04 Simpson, Robert 251.15 Singleton, John 234.06, 336.01 Sinnott, Brendan 337.32 SINS team, 128.04 Sion, Edward 338.06 Sion, Edward M. 126.06, 338.04, 338.05, 338.07, 338.09 Sion, E M. 341.02 Sirbu, Dan 253.05 Sirianni, Marco 254.27, 258.27 Sitarski, Breann 339.17, 434.11, 434.15 Sitko, Michael 257.09 Sitko, M. 340.19, 340.29 Sivakoff, Gregory 158.05 Sivaramakrishnan, Anand 413.05D 434.49 Sivarani, Thirupathi Sivin, Nathan 129.04 Sjoberg, George 338.14 Sjouwerman, Lorant 154.05, 246.07 Skemer, Andrew 257.09 Skibba, Ramin 222.07, 249.06 Skibba, Ramin A. 417.08 Skiff, B 343.01 Skillman, Evan 147.10

Skillman, E. 233.05 Skillman, Evan D. 309.05 Skillman, E. D. 335.28 Skillman, Samuel W. 149.14 Skinner, Gerald K. 434.01 Skinner, Steve L. 338.19 Skrutskie, Michael 333.03, 337.24 Skrutskie, Michael F. 406.02D SLACS Collaboration, 347.05 Slane, Patrick 256.14 Slane, Patrick O. 434.07 Slanger, Tom G. 319.07 Slater, Stephanie 405.04 Slater, Stephanie J. 405.03, 405.05 Slater, Timothy F. 405.03, 405.04, 405.05 Slavin, Jonathan 434.34 Slavin, Shawn D. 346.11, 346.12 Slawson, Robert W. 140.04, **140.12** Slee, Bruce 146.11 Slesnick, Catherine L. 339.12 Sloan, Greg 258.28 Sloan, Gregory C. 254.21, 254.22 Sloan Bright Arcs Survey Team, 347.01, 347.03 Slosar, Anze 222.06 Slyz, Adrianne 424.03D Smadja, G. 308.01 Smadja, Gerard 308.04 Smadja, G 337.13 Smail, Ian 202.09, 233.04, 430.28 Smale, Alan P. 201.09 Smart, Brianna 258.26 Smee, S. A. 433.12 Smidt, Joseph 249.03, 249.04 Smith, Adam B. 116.06 Smith, Allan W. 157.15, 348.03 Smith, Britton D. 256.20 Smith, Beverly J. 342.01 147.02, 252.03 Smith, Chris Smith, David A. 336.06 Smith, Daniel M. 145.10 Smith, David M. 404.03 Smith, Erin C. 132.06 Smith, Howard 323.05 Smith, H. A. 252.17 Smith, Howard A. 255.03, 258.07 Smith, Horace A. 311.03D

Smith, HA. 340.13 Smith, Ian 344.09 Smith, J. A. 252.15 Smith, Jeffrey C. 103.02, 140.08 Smith, J D. T. 255.08 Smith, J.D. T. 255.14 Smith, Krista 142.58 Smith, Krista L. 310.05 Smith, Keith T. 112.04 254.14, 344.16 Smith, Linda Smith, Myron 140.06, 140.16 Smith, Malcolm 149.10, 335.29 Smith, Martin 430.41 Smith, Nathan 337.36, 409.05 Smith, Paul S. 408.04 Smith, Randall 425.03 Smith, Robert C. 337.32 Smith, R. K. 114.07 Smith, Verne V. 242.01 Smith, Wesley P243.28 Smolinski, Jason P. 434.49 Smtih, J. Allyn 250.02 Smythe, Robert 253.11 256.09 Snedden, S. Sneden, Christopher 153.08, 153.13 Sneden, Chris 154.03 Sneden, Christopher 242.12 251.20 Snow, Theodore P. Snowden, Steven L. 344.17 Soares-Santos, Marcelle 239.04 Sobeck, Jennifer 153.13 Sobel, Rebecca 157.06 Sobolewska, Malgorzata 142.33 Soderberg, Alicia M. 337.15 Soderblom, David 140.14, 254.27 Soderblom, David R. 254.17 Sodre, Laerte 109.05 Soechting, Ilona 335.29 Sohn, Bong W. 430.21 Sohn, Sangmo T. 337.18 Sokal, Kimberly 158.05 Sokol, Josh 340.01 Sokolov, Igor V. 429.05 319.02 Solar Dynamics Observatory Team, Solontoi, Michael 252.11 Somerville, Rachel S. 335.01

Song, Inseok 242.16, 322.05 Song, Jeeseon 334.03 Sonneborn, George 144.19, 154.08 105.07 Sorathia, Kareem Soria, Mary 433.10 Soria, Roberto 143.02 Soriano, Melissa 413.03 Soummer, Remi 344.18 Souza, Steven P. 306.05 Sowinski, Ken 413.01 Sozzetti, Alessandro 343.03 Spadafora, A 249.10 Spadafora, A. L. 249.09 Spadafora, Anthony L. 308.05D Sparks, Robert T. 248.03 Sparr, Leroy M. 157.07 Spatzier, Alex 139.01 Speck, Angela 112.05, 250.11, 250.12, 250.14, 250.15 Speck, Angela 250.16 Speck, Angela 405.06, 405.07 Speck, Angela K. 112.06 151.03 Spekkens, Kristine Spencer, Meghin 242.20 Spencer, Michelle 342.09 Spergel, David 254.29 Spergel, David N. 253.12 Spezzi, Loredana 258.27 Spiegel, David S. 402.05 Spilker, Justin 331.04 Spittler, Connie 425.05 Spitzer Cygnus-X Survey Team, 258.07 433.14 Spjut, Erik SPLASH collaboration, 207.02, 207.03 Spoon, H. W. W.. 254.21 Spoon, Henrik W. W. 254.22 Springer, Wayne 157.10 Spuck, Tim 142.43, 248.12 Spuck, Timothy S. 252.04 SpUDS team, 335.51 Squires, Gordon 248.11, 252.04 Squires, Gordon K. 420.03, 420.04, 430.25 Sridharan, T K. 416.03D Srinath, Srikar 152.16 Srinathan, Arpitha 247.10 Srinivasan, Sundar 153.15, 154.04, 232.01 Stabile, Frank 242.27
Stacy, Athena 133.02D Staff, Jan E. 341.06 Stage, Michael D. 256.17 Staggs, Wayne D. 256.33 Staguhn, Johannes 229.04, 313.05 Staguhn, Johannes G. 430.23 Stairs, Ingrid 234.05 Stairs, Ingrid H. 139.05, 139.06, 234.01 Stanford, Darryl 257.08, 346.09 Stanford, Spencer 333.11 Stanford, Spencer A. 106.01 Stanford, S. A. 249.09 Stanford, S A. 308.05D Stanimirovic, Snezana 241.01, 241.02, 241.04, 241.06 Stanimirovic, Snezena 433.13 Stanimrovic, Snezana 241.03 Stanke, Thomas 255.15 Stankiewicz, M. 152.06 Stapelfeldt, Karl 333.05, 339.01, 339.08, 340.24 Stappers, Ben 234.05 Stappers, Benjamin W. 234.01 Stark, David V. 309.01D, 334.14 Stark. Michele A. 142.03 Stassun, Keivan 242.29 Stassun, K. 252.09 Stassun, Keivan 252.15, 334.12 Stassun, Keivan G. 153.05, 307.03, 432.18 140.20, 340.21, 340.32 Stauffer, John Stauffer, John R. 144.22, 220.05 Staveley-Smith, Lister 256.27 Stawarz, Lukasz 106.03D Steeghs, Danny 144.24 Steele, Matthew M. 409.02D Steer, I. 344.08 Steffen, Jason H. 103.05, 140.13 Stefl, Stan 339.24 Steidel, Charles C. 211.05, 335.06, 407.05, 430.15 Stein, William 338.14 Steinberg, Jean-Louis 146.08 Steinbergs, Emma 248.13, 340.08 Steiner, James 432.14 Steiner, J F. 143.04 Steiner, James F. 404.02 Steinfadt, Justin 341.08 Steinfadt, Justin D. 126.01D Stellmach, Stephan 311.01

Stencel, Robert 158.11, 257.02, 257.03 Stencel, R. 257.04 Stencel, Robert E. 158.12, 257.01, 257.07, 257.08, 257.09 Stensland, Jared 152.05 Stepanov, Rodion 434.38 Stephens, Thomas E. 254.35 Stephenson, F 129.01 Stephenson, F. R. 146.01, 146.02, 146.07, 146.11 Sterling, N. C. 256.04 Sterling, Nicholas C. 256.05 Stern, Daniel 142.42 Stern, D. 249.09 Stern, Daniel 333.11, 333.15, 335.21, 430.12 Sternberg, Amiel 202.08 Sternberg, Assaf 434.30 Stetson, Peter 152.20, 152.21, 152.22, 152.23 Stetson. P. 152.24 152.25, 152.26, 152.27, 311.04 Stetson, Peter Stetter, Tim 248.09 Stevans, Matthew L. 142.36 Stevens, J. 323.06 418.01 Stevenson, Kevin Stevenson, Kevin B. 402.02, 418.02 Stevenson, Matthew A. 142.01, 142.02 Stewart, Nathan 433.26 140.01, 140.05, 201.06 Still, Martin Still, Martin D. 140.02, 140.07, 201.09 Stilp, Adrienne 147.08, 147.09, 147.10 Stinebring, Dan 139.01, 139.02 STING collaboration, 417.04 Stinson, Gregory S. 409.01 Stock, Joseph 254.19 Stock, Nathan 431.01 Stockdale, Chris 338.14 Stocke, John 434.04 Stocke, John T. 345.11, 345.12 Stockton, Alan 310.07, 422.01 Storchi-Bergmann, Thaisa 310.01 Storm, Shave 340.10 Storrs, Alex 156.07, 346.02 Stott, Jonathan 340.11 Stovall, Kevin 139.08, 234.01, 234.05, 336.12 Strader, J. 252.14 Strader, Jay 312.02D Straizys, Vytautas 340.11 Stratman, Lee 251.28, 251.30

Straughn, Amber 335.19 Straughn, Amber N. 335.18 Strauss, Michael 230.05, 430.11 Strauss, Michael A. 142.40, 222.06, 230.01, 245.12, 252.01 Strauss, M. A. 252.17 Street, Rachel 220.01 Strelnitski, Vladimir 142.37, 249.01, 251.21 Strelnitski, V. 339.16 Strelnitski, Vladimir 340.15, 340.27 Strickland, D. K. 114.07 Stringer, Christopher 311.02D 411.03D, 434.30 Stringfellow, Guy S. Strolger, Louis-Gregory 337.14 Strom, Allison 142.05 Strom, Richard 146.11 Strom, Steve 258.04 Strom, Stephen E. 420.05 Strovink, Mark 308.05D Strubbe, Linda 303.03D Stubbs, Christopher W. 157.15, 348.03 Stuermer, W. 239.04 Sturch, Laura 311.04 Sturm, Eckhard 202.08, 421.04 Sturmann, Judit 242.03, 257.03, 343.07, 415.04 Sturmann, Laszlo 242.03, 257.03, 343.07 Sturmann, Lazlo 415.04 Stutz, Amelia 255.15 Stutz, Amelia M. 202.03 Su, Kate 339.01, 339.08, 339.14 Su, Kate Y. L. 434.19 148.02 Su, Yuanyuan Subasavage, John P. 341.01 Subbarao, Mark 252.04 Subsavage, John P. 242.05 Suc, Vincent 253.02 Sudol, Jeffrey J. 405.02 Sugerman, Ben 337.22 Sukhbold, Tuguldur 231.06 Sullivan. Ian 249.02, 249.03 Sullivan, Mark 308.07, 335.40, 337.11, 337.29, 423.01 Summers, Frank 251.16 227.05D, 335.51 Sun, Ming Sunayama, Tomomi 249.06 Sunbury, Susan 431.05 337.32 Suntzeff, Nicolas B. Supernova Cosmology Project, 249.09, 249.10, 308.05D

superWASP Team, 402.02 Surace, Jason 430.25 Sutter, Paul M. 109.04D Sutter, Paul M. 213.03D Suyu, Sherry H. 252.22 Suzuki, K 249.02 249.09 Suzuki, Nao Suzuki, N 249.10 Suzuki, Nao 308.05D, 337.11 Svoboda, Brian E. 149.12, 339.15 Swank, J 254.42 Swartz, Douglas 115.02D Swartz, Doug 434.01 Swartz, Douglas A. 143.02 Swatzell, Matthew 247.10 Sweigart, Allen V. 152.12 Swift, Brandon 434.15 Sylvestre, Nicole 252.07, 252.08, 252.21, 252.25 Sylvestri, Nicole 252.18 Syphers, David 142.16 Sypniewski, Adam J. 150.04 SZA Collaboration, 227.04D Szabo, Thad 430.39 Szalay, Alexander S. 204.05D Szentgyorgyi, Andrew 413.07 Szkody, Paula 126.06, 338.04 Taam, Ronald E. 337.05 Taber, Timothy 142.09 Taber, Timothy M. 246.06 Tacconi, Linda 202.08 Tacconi, Linda J. 430.28 Tadhunter, Clive 115.04 Tae-Ho, Lim 251.24 Takami, M 157.03 Takami, Michihiro 340.14 Takamiya, Marianne 258.31, 258.33 Takamiya, Marianne Y. 114.01 Takanashi, N 249.10 Takanashi, Naohiro 308.05D Tam, Yung H. Ng. 142.09 Tamura, Kazuyuki 142.59 Tamura, M 339.05 Tan, Jonathan 258.09 Tan, Jonathan C. 216.04D Tan, Thiam G. 338.14 Tanaka, Takamitsu 404.04D

Tang, Sumin 201.07 Tanner, Angelle M. 242.05 Tantawi, Sami 433.10 Tanvir, N. R. 141.01 Tanvir, Nial R. 108.02D Tao, C. 308.01 Tao, Charling 308.04 Tao, C 337.13 Tappert, Claus 126.05 Tarbell, Theodore D. 155.09 Tartar, Josh 112.05 Tarter, Jill C. 240.05 Taurus Spitzer Legacy Team, 131.01, 340.24, 411.05 Tavani, Marco 434.06 Taylor, Brian 241.15 Taylor, Corbin J. 256.23 Taylor, Gregory B. 142.01, 142.02, 142.31, 142.44 Taylor, Greg B. 229.02D Taylor, Gregory B. 413.03 Taylor, Joanna 153.16 Taylor, Lisa 311.03D Taylor, Rhys 312.01D Taylor, Roger S. 248.04 Taylor, Tatiana 326.06 Tchernyshyov, Kirill 255.07 Tecza, Matthias 148.08, 253.10 Teets, William K. 340.30 Teitler, Seth 342.14 Telesco, C M. 157.03 Telford, Olivia 155.03 Templeton, Matthew 338.14 ten Brummelaar, Theo 242.03, 257.03 ten Brummelaar, Theo A. 343.07, 415.04 Tendulkar, Shriharsh 157.11 Tenenbaum, Peter 140.05 Tenerelli, Domenick 253.12 Teng, Stacy H. 125.02 Tenn, Joseph S. 146.12, 210.03 Tennant, Allyn F. 143.02 Teplitz, Harry 333.06, 333.18, 334.09, 344.05, 407.08 Teplitz, Harry I. 334.10, 335.20, 407.05, 407.07 Terbeek, Brad 258.26 Terebey, Susan 131.01, 258.12, 340.21, 340.24 Terebey, S. 411.05 Terek, S. 344.08 253.09, 401.01, 401.02 Terrien, Ryan

Teske, Johanna 431.01 Testa, Paola 155.05 Testor, Gerard 258.28 Thacker, Robert 433.23 Thaler, Jon 239.03 Thatte, Niranjan 148.08, 253.10 The, Lih-Sin 242.14 Theijsmeijer, Heather 158.08 246.22 Thilker, David Thilker, David A. 112.03 Thirumalai, Anand 232.03 257.04 Thizy, O. Thom, Chris 335.09 Thomas, Brian 155.06 Thomas, Beth 248.10, 342.03 Thomas, Brian 349.01 Thomas, Daniel 142.08 Thomas, Rollin 308.01 Thomas, Rollin C. 308.04 Thomas, R C. 337.13 Thompson, Donna 116.08 Thompson, Ian 153.13, 154.03 Thompson, Ian B. 434.30 Thompson, Jonathan 335.25 Thompson, Matthew 334.08 140.06 Thompson, Randall Thompson, Susan E. 140.01, 140.03 Thompson, Todd 246.11 Thomson, Ellen 251.28, 251.30 Thomson, Mark 253.12 Thorman, Paul 252.15 Thureau, Nathalie 257.03 Tilleman, Trudy 306.05 Timmes, Frank 341.09, 434.24 Timmes, F X. 308.02 Timmes, F. X. 319.01, 324.06D, 337.01 337.06 Timmes, Frank X. Timpe, Miles L. 343.22 Tingay, Steven 256.27 Tinker, Jeremy 249.06, 249.07, 412.04D Tobin, John 255.15 Tobin, John J. 131.04D Todd, Nathan 252.07, 252.08, 252.18, 252.21, 252.25 Todorov, Petar 432.26 Tofflemire, Benjamin M. 251.02 Tohline, Joel 341.06

Tohline, Joel E. 126.03, 341.07 Tokarz, Susan 153.16 Tokita, Kouichi 308.05D Tokunaga, A 157.03 Tokunaga, Alan 257.09 Tollerud, Erik J. 147.03 Tomczak, Adam 149.06 Tomsick, John A. 240.07 Tonnesen, Stephanie 241.03 Tonry, John 312.03 Toomey, Douglas W. 253.10 Toomre, Juri 155.12, 242.22 Torcolini, Nicole B. 248.14 Toro Martinez, Irene 434.30 Torres, Guillermo 103.03, 140.05, 201.02, 343.03 Torres, Manuel A. P.. 144.24 Torres, Rosa M. 434.46 Touhami, Yamina 406.03 Tourtellotte, Suzanne 126.04 Townsend, Rich 154.02 Townsend, Shonda 142.05 Townsley, Dean M. 126.06, 308.02, 324.06D, 337.01 Townsley, Leisa 144.26 409.05 Townsley, Leisa K. Tr'Ehnl, Nahks 319.01 Trakhtenbrot, Benny 230.01 Trammell, George 158.05 Tran, Hien D. 142.52 Tran, Kim-Vy 149.19 Trancho, Gelys 152.08, 152.35 Traub, Wesley 157.12 Traverse, Abby 248.14 Traweek, Sharon 431.06 Traxler, Adrienne 311.01 Treister, Ezequeil 233.04 Treister, E. 252.17 Treister, Ezequiel 326.01, 326.02D, 335.23, 407.02 Tremaine, Scott 422.05 Tremblay, Steven 229.02D Tremblay, Steve E. 413.03 Tremonti, Christy 326.03, 335.14 Trenti, Michele 143.03 Treu, Tommaso 148.05, 335.40, 347.05, 430.01, 430.18 Treuthardt, Patrick 246.09, 246.15 Trigilio, Corrado 130.01 Trilling, David 433.11

Trilling, David E. 252.10 Trimble, Virginia L. 210.04 Trinh, Chris 147.03 Tripathy, Sushant 155.04 Tripp, Todd 345.09, 430.37 Trippe, Margaret 142.29 Troischt, Parker 149.30 Troitskii, Ivan S. 142.55 Troland, Thomas 434.32 Trombley, Christine 241.07 Tromp, Jillian 131.01 Troost, Tobias 113.01 Trouille, Laura 326.03 Trowbridge, Sarah 256.16, 434.31 340.04 Troy, Mitch Truitt, Amanda 142.45 Trump, Jonathan R. 211.04, 430.08 Truong, Thien-Tin 156.12 Tsai, Chao-Wei **333.11**, 333.12, 333.14, 333.15 Tsalmantza, Paraskevi 345.06 Tsang, David 322.04 Tseng, Shui-Ay 140.06 Tsumura, Kohji 249.03 Tsvetanov, Zlatan I. 429.07 Tucker, Bradley E. 403.04 Tucker, Corey 157.07 Tucker, Carole 313.05 Tucker, Douglas 334.03, 347.01, 347.02, 347.03 Tucker, Douglas L. 245.12 Tucker, Faith 431.03 Tueller, Jack 125.01, 326.02D Tuellmann, Ralph 246.10 Tully, R. B. 147.07, 328.02D Tumlinson, Jason 254.17, 254.27, 335.09 Tupa, Peter R. 144.05 Turner, Jane 142.13 Turner, James 149.29 Turner, Jake 258.26 Turner, Nils 242.03, 257.03 Turner, Nils H. 343.07, 415.04 Turner, Rebecca 158.11, 158.12 Turriziani, Sara 125.03D Tussey, Joshua M. 256.33 Twarog, Bruce 153.10 Twicken, Joe 140.01 Twicken, Joseph 140.05

Twicken, Joseph D. 103.02, 140.08 Tyler, Krystal 431.01 Tyson, J. Anthony 252.23 Tyson, J. A. 252.01, 252.19, 252.24 Tyson, John A. 335.32 Tzanavaris, Panayiotis 152.07, 335.07 Tzioumis, Anastasios K. 256.27 Tzioumis, T. 323.06 335.30 U, Vivian U.S. LISA Mission Science Office, 347.08 UCF Exoplanet Team, 402.02 Udomprasert, Patricia 420.05 Ueltzhoeffer, Kai 253.02 Ule, Nicholas 201.04 425.06 Ulmer, Melville P. Umana, Grazia 130.01 UNM Measurement Astrophysics (MAP) Research Group, 157.05 Unwin, Stephen C. 142.23, 157.12 Updike, Adria C. 108.01D, 251.25 Urban, Laurie 340.05 Urquhart, James 411.04 Urry, C. Megan 326.01, 408.01 Urry, C. M. 335.23 Urry, Meg 106.04, 142.50, 233.04 US Planck Collaboration, P243.28 Uzpen, Brian 258.25 Vaccari, Mattia 430.29 Vaisanen, Petri 148.03 Valenti, Jeff 140.14, 254.17, 254.27, 415.06 Vallisneri, Michele 225.04, 347.08 Valva, Annie 420.05 van Altena, William F. 152.40 van Arkel, Hanny 106.04, 142.08 van Belle, Gerard 242.03, 302.06 van Belle, Gerard T. 242.23, 415.04 van Cleve, Jeffery 140.01 Van Cleve, Jeffrey E. 140.08 van den Berg, Maureen 434.08 van den Bosch. Frank 249.06, 249.07 van den Bosch, Frank C. 249.08, 309.06, 335.34, 335.35 van den Bosch, Remco C. E.. 106.07, 403.03D van der Bliek, Nicole S. 226.05D van der Marel, Roeland 207.04D van der Marel, Roeland P. 424.04D van der Marel, Roeland P. 246.05, 337.18 van der Meere, Carel 432.06

Van Der Veen, Ei	rik	258.18	
Van Der Veen, Jatila		P243.28	;
van der Veen, Wil E.		209.07	
van der Wel, Arjen		213.05,	335.47
van der Werf, Paul		233.04	
van Dishoeck, Ewine		258.05, 2	258.09, 340.35
Van Dyk, Schuyler D.		410.03	
Van Etten, Adam		336.04	
Van Eyken, Julian C.		220.05	
van Haaften, Lennart 1		144.24	
van Leeuwen, Joeri 234.01, 234.05			
Van Wassenhove, Sandor 432.21			
Van Winkle, Dan		433.10	
van Zee, Liese	147.11		
van Zee, L.	147.12		
van Zee, Liese	417.03		
VanCleve, Jeffrey	/	103.02	
Vanden Berk, Daniel E.		250.07	
Vanden Berk, D. E.		252.17	
Vander Plas, Jake		151.06	
VanDerMolen, Jennifer		248.13, 3	340.08
VanderPlas, Jake		153.04	
VanHamme, Walter		144.06	
Varlotta, Angelo	144.29		
Varri, Anna L.	152.10		
Vasisht, Gautam	344.18, 4	13.05D	
Vavrek, Roland	255.04		
Vayonakis, Anastasios 413.04D			
Vazquez-Semade	ni, Enriq	ue	434.36
Vega, Laura	338.12,	338.13	
Vegetti, Simona	225.01		
Veilleux, Sylvain	127.03D	, 202.08,	326.02D
Velur, Viswa	340.04		
Veneziani, Marce	lla	112.08	
Venkataraman, A	run	234.01	
Venkatesan, Apar	ma	231.03	
Venn, Kim	434.48		
Venter, Christo	215.04E)	
Vera, Eduardo	344.13		
Verde, Licia	222.06,	222.07	
VERITAS,	144.29	, 408.05	
Verma, Aprajita	202.08		
Vernstrom, Tessa		432.07	
Vesperini, Enrico 152.15			
Viana, Alex	254.39		
Vican, Laura	434.09		

Vijh, Uma P. 250.01 Vikhlinin, Alexey 149.10, 149.12 Villamil, Cindy 140.10, 144.04 Villaume, Alexa 340.15, 340.27 Villforth, Carolin 408.03D Vilsoet, Anne 337.07 Vincent, Chelsea 256.25 130.03D, 130.05 Vink, Jacco Vinko, Joszef 434.28 Vinkovic, Dejan 256.02 Virani, Shanil 106.04 Virgo Collaboration, 432.27 Vishniac, Ethan T. 417.07 Visser, Ruud 258.05, 258.09, 340.35 Viti, S. 255.03 Vivas, A. Katherina 241.17 Voelk, Heinz 325.05 Voellmer, George 313.05 Vogel, Stuart N. 309.01D, 334.14 Vogeley, Michael S. 204.03D Vogelsberger, Mark 417.06 Voges, Wolfgang 430.13 Vogt, Nicole P. 246.16 Volegova, Antonina 434.38 Volk, Kevin 153.15 Voll, Patricia 433.10 Volonteri, Marta 128.01D, 432.21 von Braun, Kaspar 220.03, 220.05, 242.03, 242.23, 415.04 von Kienlin, Andreas 434.01 Vorobiev, Dmitry V. 157.05, 157.15 Vorobyov, Eduard 335.49 337.18 Voss, Rasmus Voyer, Elysse 233.01D Voyer, Elysse N. 335.20 Vrba, Fred J. 226.05D, 340.11 Vrsnak, Bojan 252.10 Vy-Tran, Kim 149.06 Waagan, Knut 251.06 Wachter, S. 333.08, 333.09 Wachter, Stefanie 333.10 Wacker, Bronson 335.14 Waczynski, Augustyn 254.12 Wada, Keiichi 335.48 Wada, T 249.02 Wada, Takehiko 249.03 Wade, Richard A. 201.03

Wadsley, James 241.11, 328.05 Wagg, Jeff 335.21, 430.11 Wagner, Christian 127.04 Wagner, Cory R. 335.47 Wagner, Mark 240.06 Wahhaj, Zahed 253.10 Wahl, Matthew 335.36 Wahlgren, G. M. 154.06 Wahlgren, Glenn M. 154.07 Wake, David 249.06 Wakker, Bart 251.28, 251.30, 345.04 Walborn, Nolan 144.26 Walcher, Carl J. 246.05 Walcowicz, Lucianne 343.02 Waldron, Wayne 154.10 Walker, Alistair 153.10 Walker, Alastair 252.03 Walker, Constance 349.07 Walker, Constance E. 158.10, 248.07 Walker, Gary 142.37 Walker, G. 339.16 Walker, Gary 340.15, 340.27 Walker, Jean P. 407.01 Walker, Lisa May 158.05, 335.04, 335.07 Walker, Matthew 432.21 Walkowicz, Lucianne M. 201.05, 252.12 Wall, Jasper V. 432.07 Wall, R.J. 257.09 Wallace, Colin S. 247.04 Wallace, Spencer 258.26 Wallerstein, George 257.05, 342.17 Walsh, Andrew 146.03 Walsh, Jonelle 106.07 Walsh, Jeremy 335.19 Walter, Donald 140.11, 342.13 Walter, Donald K. 145.10, 342.12 Walter, Fabian 133.04D, 147.10, 202.07, 233.04, 246.14, 335.21 Walter, F. 340.19, 340.29 Walter, Fabian 430.11 Walter, Frederick M. 226.05D, 338.11, 338.14, 340.34 Walter VanHamme, Florida Interational University, 144.14 Walterbos, Rene 246.21, 246.22 Wang, Chih-Yueh 434.39 Wang, Junfeng 144.26 Wang, Junxian 326.08 Wang, Ji 334.12

Wang, Lingyu 255.09 Wang, Qian 232.02D Wang, Ran 430.11 Wang, Sheng 225.02 Wang, Weisong 433.05 Wang, Xuesong 253.08 Wang, Zhi-fu 234.06 Ward, M. J. 114.07 Ward-Duong, Kimberly 148.01 Wardle, M. 323.06 Warner, C 157.03 Warner, Craig 157.18 Warren, Steven 147.08 Warren, Steven R. 147.10 Wasserman, Ira M. 432.11 Wasserman, Larry 340.18 Watkins, Tiffany 157.01 Watry, Aaron 344.06 Watson, Alan 157.07 Watson, Chris 158.13 Watson, Christer 241.14, 241.16, 251.18 Watson, Dan 255.15 Watson, Dan M. 255.04 133.03D Watson, Linda C. Wayth, Randall 116.07 158.06 Weaver, D. Weaver, Elise 116.06 Weaver, Robert 156.09 Webb, Natalie 432.17, 432.25 Webster, Rachel L. 326.07 Wechsler, Risa 249.07 Wechsler, Risa H. 213.06, 249.08 Wegner, Gary 127.01D Wehner, Elizabeth M. 312.02D Wehrle, Ann E. 142.23 Wei, Jianyan 425.04 309.01D, 334.14 Wei, Lisa H. Weigel, Catherine 149.30 Weigelt, Gerd 338.17 Weijmans, Anne-Marie 422.04 Weinberg, David 249.06 Weinberg, David H. 222.06 Weinberg, Martin 430.34 Weinberg, Martin D. 207.01 Weinberger, Alycia J. 340.12 Weiner, Neal 432.10

Weintraub, David A. 340.30 Weinzirl, Tim 335.22 Weiss, Axel 245.09, 246.11 Weiss, A. 323.06 Weisz, Dan 147.08 Weisz, D. 233.05 Weisz, Daniel R. 309.05 Weisz, D. R. 335.28 Welch, Doug L. 337.32, 434.19 Welch, Tanner J. 149.12 Welling, Christine 142.54 Wellnitz, Dennis D. 349.04 Wellons, Sarah 337.15 Wells, Akeem J. 252.13 Wells, William 146.04 Welsh, Barry 251.31, 339.11 Welsh, Barry Y. 338.15 Welsh, William 140.17 Welsh, William F. 103.07, 140.04, 140.13, 201.03 Wen, Linqing 432.23 Wen, Yiting 254.12 Wendt, Harry 146.10 Wennerstrom, Elizabeth 434.37 Werk, Jessica K. 327.06 Werk, J K. 345.09 Werner, Michael 339.08 Werner, Michael W. 142.38 Wertheimer, Dan 240.03 Werthimer, Dan 240.06 Wesley, Anthony 156.08 Wesson, Roger 337.22 West, Andrew A. 226.05D, 242.02, 242.19, 242.20, 250.04, 307.03, 434.11 West, Michael 149.17 West, Michael J. 149.02, 312.03 West, Richard G. 418.02 Wester, William 239.03 Wester, W. 239.04 Wetzel, Andrew 249.06 Wezgowiec, Marek 245.01 WFC3 SOC, 152.06, 245.03, 246.17, 258.27, 312.04, 335.18, 335.19 WFC3 Team, 254.36, 254.37, 254.38, 254.39, 254.40, 254.41 Wheatley, Jonathan 251.31 Wheatley, Peter J. 402.02, 418.02 Wheeler, John C. 434.28 Wheeler, J C. 434.30 Wheeler, Jordan D. 250.13

Whelan, David 158.05 Whelan, David G. 258.20 Whimex Science and Instrument Teams, 433.01 Whitcomb, Stan 432.23 White, Amanda 436.02 White, Glenn J. 323.05 White, Martin White 127.04 White, Martin 150.05, 222.06, 222.07, 249.06 White, Russel 242.03 White, Rick 344.07 White, Russel J. 242.16, 343.07 White, Richard L. 106.01 White, Vivian 158.01 Whitehorne, Mary Lou 420.02 Whitmore, Bradley C. 152.06, 246.12, 246.17 Whitmore, Jonathan 412.01D 241.14, 241.16, 257.09, 258.28 Whitney, Barbara Whitney, Barbara A. 258.20, 340.31 Whittingham, Ian 146.11 Whittington, Alan 112.05 Whitworth, Christi 346.14 Whole Earth Telescope, 341.05 Widhalm, Allison M. 152.35 Wiecha, Oliver 252.05 Wielebinski, Richard 146.11 Wiesemeyer, H. 323.06 Wiesner, Matthew 347.01 Wiesner, Matthew P. 347.02 WiggleZ Dark Energy Survey team, 204.01 Wigley, Elizabeth 248.13, 340.08 Wiita, Paul J. 212.07 Wijnands, Rudy 144.24, 432.12 Wiktorowicz, Sloane **318.04**, 434.34 Wiktorowicz, Sloane J. 339.04, 429.09 127.05, 149.01, 149.07, 149.31 Wilcots, Eric Wilcots, Eric M. 115.03, 149.26, 335.11, 430.03 Wiley, Keith 344.12 Wilhelm, Mary B. 340.04 Wilka, Catherine 433.11 Wilkes, Belinda J. 230.04 142.50 Wilkin, William H. Wilking, Bruce A. 131.02D Willems, Bart 105.04 Willett, Kyle 114.02D Willett, R. 256.12, 256.13 Williams, Anna 147.16

Williams, Benjamin 207.02, 207.03, 252.15 Williams, Ben 253.06 Williams, Benjamin 328.01 Williams, B. F. 152.19 Williams, Benjamin F. 233.05, 246.10, 430.13 Williams, Brian J. **256.21**, 256.22 Williams, Darren M. 402.03 Williams, Jedediyah 340.27 Williams, Jonathan P. 113.01, 217.01, 339.09 Williams, Peter K. 240.07 Williams, Rosa Nina 256.30 Williams, Roy 334.02 Williams, R 334.17 Williams, Rik J. 340.31 256.29 Williams, Rosa N. Williams, Thomas R. 210.02 Williger, Gerard 340.19 Williger, G. 340.29 Willman, Beth 147.17 Willman, B. 252.14 Willman, Beth 424.01 Willmer, Christopher 114.01, 149.19, 258.33 Willner, Steve 230.04 Willott, Chris 254.27 Wills, Beverley 142.65 Wills, Derek 142.65 Willson, Lee Anne M. 232.02D Wilman, David J. 421.01 Wilmer, Christopher N. A.. 255.14 Wilner, David 340.35 Wilner, David J. 340.31 Wilson, Colleen 434.01 Wilson, Grant W. 430.23 Wilson, Thomas 255.15 Wilson, Thomas L. 216.06 Windemuth, Diana 245.08 Windhorst, Rogier A. 142.40, 142.59, 246.17, 335.18, 335.19, 347.09, 433.23 Winget, D E. 433.24 Winkler, Frank 256.29 Winkler, P. F. **256.19**, 256.21, 256.32 Winn, Joshua N. 343.03 Winter, Lisa 142.28, 142.29, 326.02D Winter, Lisa M. 142.50, 326.06 Winters, Jennifer G. 242.05, 242.26 WISE Extragalactic Team, 333.13 WISE Science Team, 333.19

WISE Team, 158.09, 333.12, 333.15 Wiseman, Jennifer J. 113.02 Wisniewski, John 242.29, 334.12 Wisniewski, J. 340.19, 340.29 Wisniewski, John P. 339.05, 339.22 Witt, Christopher 251.28 Witt, Christopher M. 251.30 Witteborn, Fred C. 254.06 Witthoeft, Michael C. 256.05 Wittman, David 252.23 Wittman, D. 252.24 335.32 Wittman, David M. Woillez, Julien 433.15 Wojtkowski, Kari A. 131.02D 306.05 Wolf, Jurgen Wolf, Sebastian 416.03D Wolfe. Arthur 309.03D Wolfe, Aaron 338.06 Wolfe, Chris 413.03 Wolfe, Michael A. 254.02, 254.03 Wolff, Michael T. 336.07 Wolff, Schuyler 156.10 Wolff, Sidney 252.03, 258.04 Wolff, Schuyler 337.14 Wolfgang, Angie 140.19 Wolfire, Mark G. 255.08 Wolfram, Kenneth D. 215.06D Wolk, Scott 144.26, 258.19 Wolk, Scott J. 340.16 Wollack, Edward 313.05 Wolszczan, Alex 253.04 Wong, Curtis 420.05 Wong, Kenneth C. 229.01D Wong, Michael H. 156.08 Wong, Tony 133.05, 251.26 Wong, Tony H. 216.05 Woo, Jong-Hak 430.10 Wood, Kenneth 258.20 Wood, Kenneth A. 251.06 Wood, Kent S. 108.06, 336.07 Wood, Matt A. 201.09 Wood-Vasey, W. M. 252.20 Wooden, Diane H. 156.03 Woodgate, B. 340.19, 340.29 Woodgate, Bruce 430.24 Woodgate, Bruce E. 254.12, 254.19

Woodley, Kristen 152.20 Woodley, Kristin 152.21, 152.22, 152.23 Woodley, K. 152.24 Woodley, Kristin 152.25, 152.26 Woods, Dan 413.03 Woods, Paul M. 114.06 Woodward, Charles E. 156.03, 306.06 Woodward, John T. 157.15, 348.03 Worrall, Diana M. 230.04 Worth, Rachel 349.03 Wotta, Christopher B. 142.34 Wright, C M. 157.03 Wright, Edward L. 158.09, 254.12, 333.02, 333.16 Wright, Gillian S. 433.06 Wright, Jason 220.03, 253.04, 415.06 Wright, Jason T. 152.29, 253.08 Wright, Ned 333.17, 333.19 Wright, Shelley 241.18, 407.06 Wright, Shelley A. 422.06 Wright, Teresa 258.32 Wrobel, J. M. 142.06 Wrobel, Joan M. 310.04, 413.01 Wu. C. 308.01 Wu, Chao 308.04 Wu, C 337.13 Wu, Catharine J. 246.21 Wu, Haley 140.05 Wu, Hao-Yi 249.07 Wu, Jingwen 333.11, 333.14 Wuyts, Eva 114.04 Wuyts, Stijn 211.04 Wyatt, Mark 419.02D Wyatt, Mark C. 419.01D Wyithe, J. S. B.. 347.09 Wyithe, Stuart 116.07 Wyman, Katherine 251.10 Wyrowski, Friedrich 113.01 Wyse, Rosemary F. G.. 147.06 Wyss, Sarah 251.26 XCS Collaboration, 430.31 Xia, Lifang 335.17 Xie, Jiwei 334.12 Xiong, Liang 153.04 149.05 Xu, Hao Yajima, Hidenobu 345.01 Yamashita, T 157.03

Yan, Haojing 128.05 142.40 Yan, Hao-Jing Yan, Haojing 335.18, 347.09 Yan, Lin 310.07, 333.11, 333.15, 430.23, 432.01 Yanamandra-Fisher, Padma 156.08, 257.09 Yang, Abel 158.05 Yang, Hsiang-Yi 109.04D, 213.03D **258.11**, 339.13, 339.18, 340.33 Yang, Hao Yang, Soung-Chul 342.16 Yang, Xiaohu 335.34, 335.35 Yanny, Brian 334.13 Yao, Yangsen 217.06 Yaqoob, Tahir 326.08 Yasuda, N. 249.09 Yasuda, N 249.10 Yasuda, Naoki 308.05D Yau, Kevin K. 333.18 Ycas, Gabriel 253.09, 401.01 Ycas, Gabe 401.02 Yee, Howard 424.01 Yeh, Sherry 132.07 Yelda, Sylvana 241.18, 303.04, 411.02 Yen, Steffi 149.18 Yi, Sukyoung 422.03 Yi, Sukyoung K. 430.36 Yniguez, Basilio 207.03, 207.04D Yoast-Hull, Tova 245.04 Yong, David 434.30 Yoon, Ilsang 430.34 York, Brian 254.01 York, Don 257.05 Yost, Sarah 141.05 Young, John 157.09 Young, Jason 421.04 Young, Lisa 312.04, 422.04 Young, Lisa M. 335.08, 422.02D Young, Michael 114.01 Young, Monica 142.42 Young, Mallory 252.07, 252.08, 252.18, 252.21, 252.25 Young, Michael 258.33 153.02, 431.01 Young, Patrick Young, Patrick A. 423.05 Young, Timothy 209.05 YSOVAR Team, 340.21 Yu, Shanshan 217.07 Yuk, In-Soo 433.08

Yukita, Mihoko 115.02D Yun, Min 430.23 Yusef-Zadeh, Farhad 258.22, **323.06** Z-Spec team, 245.13, 245.14 Zabludoff, Ann 152.07 Zadeh, Farhad 323.07 Zahnle, Kevin 418.07 Zajac, Stephanie 340.07 Zakamska, Nadia L. 142.11 Zambrano-Marin, Luisa Fernanda 306.05 Zamorano, Jaime 417.02D Zanardo, Giovanna 256.27 Zangari, Amanda M. 306.05 Zapata, Luis A. 434.44 Zaritsky, Dennis 308.06 Zasowski, Gail 158.05 Zavala, Robert 142.39 Zavala, Robert T. 348.04 Zaw, Ingyin 430.09 Zehavi, Idit 249.06 Zeiger, Ben 258.03 Zeiger, Benjamin 335.10 Zeimann, Gregory 106.01 Zell, Peter T. 254.06 Zemcov, Michael 249.02, 249.03 Zemcov, Michael B. 244.02 Zeng, Lingzhen 313.05 Zensus, J A. 142.01, 142.02 Zenteno, Alfredo 334.03 Zepf, Stephen E. 409.02D, 409.03 Zermeno, Adrienne 336.12 Zernow, Lea 148.06 Zezas, A. 114.07 Zhai, Chenxing 425.01 Zhan, Hu 252.19, 252.23 Zhang, Hongxin 147.13 Zhang, Haotong 334.13 Zhang, Hongxin X. 147.15 Zhang, Qizhou 255.03, 416.01, 416.03D Zhang, Shuang-Nan 425.04 Zhang, Tianxi 404.05 Zhang, William 254.25 Zhang, Xiao-Ling 434.01 Zhang, Yueyang 334.13 Zhao, Gang 334.13 Zhao, Hong Sheng 241.12

Zhao, Jingkun 341.03 Zhao, Ming 257.03 Zhao, Ping 434.08 Zharikov, Sergey V. 339.24 Zhekov, Svetozar 338.19 Zheng, Wei 142.16, 227.06, 254.01 Zheng, Zheng 246.13, 249.06 Zhu, Guangtun 229.01D, 430.09 Zhu, Zhaohuan 322.03D Zibetti, Stefano 417.08 Zielinski, Pawel 253.04 Zierten, Josh 434.52 Zima, W. 103.07 Zimmer, Peter 129.02 Zimmer, Peter C. 157.05, 157.15, 348.03 Zimmerman, Neil 413.05D Zingale, Michael 234.03D Zinn, Robert 241.17, 433.18 Zirzow, Daniel C. 157.05, 157.15 Zita, E. J. 436.01 Zitrin, Adi 109.05 Zmuidzinas, Jonas 413.04D Zolkower, Jeff 157.11 323.04D Zolotov, Adi Zonak, Stephanie 401.01 Zook, Alma C. 142.23, 142.26 Zschaechner, Laura 246.22, 246.23 Zucker, Daniel B. 152.28 Zuckerman, Ben 302.01, 322.05 Zugger, Michael 402.03 Zuluaga, Carlos A. 306.05 Zurek, Dave 152.20 Zurek, David 152.21, 152.22, 152.23 Zurek, D. 152.24 Zurek, David 152.25, 152.26 Zurita, Nathaly 144.13 Zweibel, Ellen 245.04 Zweibel, Ellen G. 241.19