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Presentation

The *Osservatorio Astronomico di Bologna*, one of the twelve Italian Observatories, is one of the research structures of the National Institute for Astrophysics (INAF), operating under the supervision of the Ministry for Instruction, University and Research (MIUR). The Ministry provides most of the financial resources which make our activity possible.

This Report provides an overview of our scientific research, covering a wide range of topics in astronomy such as :

- stellar population and galactic evolution studies and their cosmological implications;
- study of the structure, evolution and distribution of galaxies, clusters and AGN and their contribution to the cosmological backgrounds;
- numerical studies and software developments in the fields of the turbulence simulations and deconvolution techniques;
- management and upgrading of the two telescopes in Loiano (152 and 60 cm) and development of astronomical instruments in the framework of national and international programs.

Most of these studies are based on an intensive use of the most advanced instruments available today at all wavelengths. These are carried out in collaboration with many international and national institutes and, locally, with the *Università di Bologna, Dipartimento di Astronomia* and with the *Consiglio Nazionale delle Ricerche (CNR)*. Moreover, a large fraction of the staff is involved in international long-term projects (e.g. VIRMOS, FLAMES, ISO-ELAIS, K20 redshift survey).

For the first time this report is not signed by Bruno Marano. He has been the Director of the *Osservatorio Astronomico di Bologna* for fourteen years, from 1987 up to the end of 2001, when he has chosen to move to other responsibilities. During these years the Observatory has significantly increased in number of staff members and improved in the quality of its scientific research. We are all deeply indebted to Bruno Marano for his dedication to the Observatory and for having provided the conditions for a pleasant and fruitful work for all of us.

This report has been prepared by **Angela Bragaglia**, **Andrea Comastri**, **Giovanni Zamorani** and **Elena Zucca**, with the collaboration of Luca Ciotti, Antonio De Blasi, Marco Lolli, Monica Marra, Roberto Merighi and Valentina Zitelli.

Flavio Fusi Pecci

(Director)

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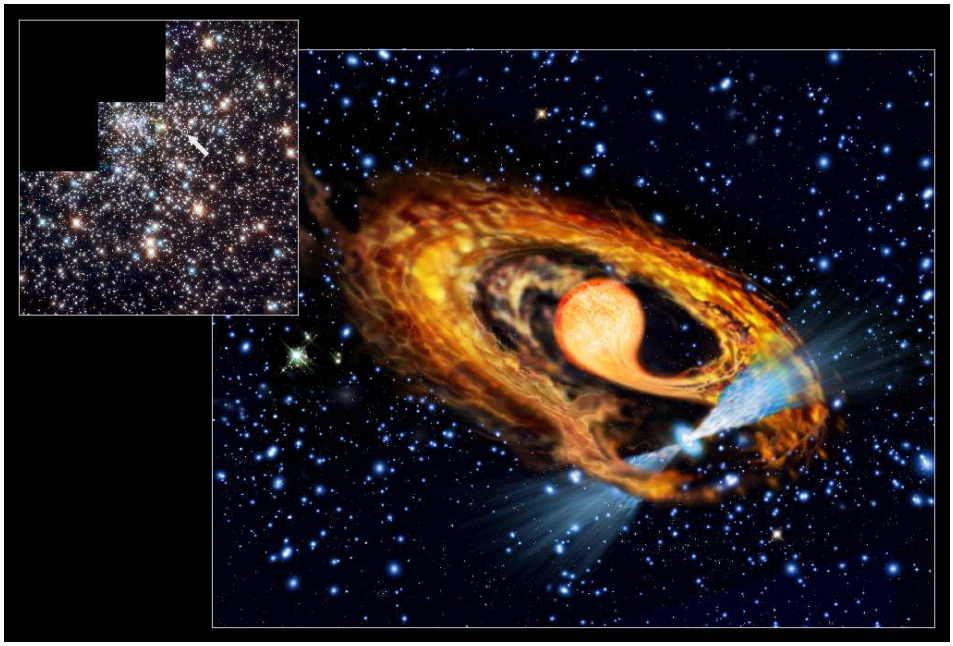


This figure presents an artist's impression of a new-born millisecond pulsar, seen in blue with two radiation beams, and its bloated red companion star. Scientists believe that the best explanation for seeing a bloated red star instead of a "quiet" white dwarf in the system is that the pulsar only recently has been spun up by the gases transferred by the red star. It is the first time such a system has been observed. The insert shows the HST image of the globular cluster NGC 6397, where this system (indicated by an arrow) has been discovered (Courtesy of D'Amico, Ferraro, Possenti and Sabbi).

Involved people at OAB:

- *Scientific staff:* M. Bellazzini, A. Bonifazi, A. Bragaglia, C. Cacciari, G. Clementini, N. D'Amico, L. Federici, F.R. Ferraro, F. Fusi Pecci, L. Greggio, L. Origlia, L. Stanghellini, M. Tosi;
- *Technical staff:* M. Lolli, P. Montegriffo;
- *Fellows:* F. Annibali, L. Baldacci, L. Di Fabrizio, S. Galleti, L. Monaco, A. Possenti, E. Sabbi

The evolution of stars and stellar systems is a very active research field of the OAB since its foundation. The interests range from evolution of galaxies to galactic and extragalactic globular clusters systems, from binaries to variable stars, from pulsars to LMXBs, covering the whole range of astronomical wavelengths.

The present short description of the activity in the year 2001 has been organized in a few main sections to provide a very general overview: 1. The evolution of the Galaxy, 2. Globular clusters, 3. Nearby Galaxies, 4. RR Lyrae Variable stars, 5. Eclipsing binaries, 6. Planetary Nebulae, 7. Pulsars.

1.1 The evolution of the Galaxy

1.1.1 Chemical evolution models

Involved people at OAB: Tosi.

Models of Galactic chemical evolution are nowadays able to reproduce the vast majority of the observed characteristics of our Galaxy. There are, however, a number of open questions on the evolution of the Galaxy, which still require further studies (e.g. Tosi 2001a). Some of these issues are being examined in detail at the Bologna Observatory. In 2001, we have proceeded in the effort of accurately analysing the feedback between stellar nucleosynthesis and chemical evolution, the evolution of the abundance gradients and the impact of Galactic chemical evolution models on cosmology. To this aim new models for D, ^{3}He, ^{4}He, ^{12}C, ^{13}C, ^{14}N, ^{16}O, ^{17}O, ^{18}O, ^{20}Ne, ^{22}Ne have been computed and compared with the available data, adopting all the most recent and reliable stellar yields.

A collaboration exists with the International Space Science Institute in Berne (Switzerland) to study all the aspects of stellar and galactic evolution affecting the abundances of the light elements. This group has applied for a NASA mission (Interstellar Pathfinder, PI Gloeckler) aimed at deriving the local medium abundances of various elements relevant for the Big Bang nucleosynthesis.

All the Galactic chemical evolution models able to reproduce the largest sets of observational constraints have shown that the primordial abundance of D and ^3He must have been fairly low. This implies that the photon/baryon ratio was fairly high during the Big Bang, a result emphasized by the Maxima and Boomerang experiments on the cosmic microwave background. Our group, in collaboration with Steigman (Ohio State Un.), Galli and Palla (Arcetri Obs.), has been particularly active in this field and has been the first in reaching these results (Tosi 2001c and references therein). Spectra of Planetary Nebulae acquired in 2001 with HST-STIS have allowed us (Palla et al. 2002) to put new stricter constraints on the still puzzling evolution of ^3He, by confirming the interrelation between ^3He and $^{12}C/^{13}C$ production and depletion in low mass stars.

1.1.2 Open clusters as tracers of the evolution of the abundance gradients.

Involved people at OAB: Bonifazi, Bragaglia, Di Fabrizio, Tosi.

Open clusters (OC's) are excellent tools to understand the evolution of the disk of our Galaxy from both the chemical and structural points of view. Many of the existing chemical evolution models are able to reproduce well the present-day situation, but differ significantly (Tosi 2001a) in the "history" of the chemical enrichment (hence in the involved processes). In particular, they differ in the predictions for the evolution of the abundance gradients: does the gradient slope steepen or flatten with time? From the OC's we can extract fundamental information, since they can be used to describe the run of the various elemental abundances at different ages.

In order to study in more detail the metallicity and age distribution with galactocentric distance, we are analyzing with great accuracy a large sample of open clusters (our goal is to have at least 30 OC's) at various galactic locations and covering a wide range in age and metallicity. Age, distance modulus, reddening and approximate metallic-

ity of the clusters are derived from their Color-Magnitude Diagrams (CMDs) using the synthetic CMD technique and further constrained by the observed luminosity functions. Precise and homogeneous elemental abundances are determined from high resolution spectroscopy.

During 2001, we have completed the interpretation of Pismis 2 in terms of evolutionary parameters (Di Fabrizio et al. 2001) and started that of Be 22, Be 29, NGC 4815 and NGC 6939.

Up to now only about 25 % of the ∼80 old OC's have ever been studied with high resolution spectroscopy, and only a handful have abundances of elements other than iron. To widen the sample, we have obtained high-res spectra of red clump stars in a dozen of OC's, with FEROS@1.5m ESO, SARG@TNG, and UVES@VLT: analysis is completed for NGC 6819 and under way for the others (Bragaglia et al. 2001a, 2001c, 2002; Carretta et al. 2002). Preparatory work for FLAMES@VLT GTO observations has also begun in 2001.

This research is in collaboration with Carretta and Gratton (Padova Obs.), Marconi and Andreuzzi (Roma Obs.).

1.1.3 Field Blue Horizontal Branch (BHB) stars and RR Lyrae as tracers of the galactic halo

Involved people at OAB: Bragaglia, Cacciari.

The field BHB stars, along with the RR Lyrae variables and the carbon stars, are excellent tracers of the galactic halo stellar population. A detailed knowledge of their chemical and dynamical characteristics is therefore essential to understand how the Galaxy formed (e.g., hierarchical accretion/merging processes).

The questions of whether the high galactic halo is in retrograde rotation and how the velocity dispersion and flattening of the halo vary with height above the galactic plane are still controversial. They could be settled by studying halo stars nearer than about 10 kpc. In collaboration with Kinman (NOAO), Buzzoni (TNG) and Chavez (Mexico) we are studying a sample of about 150 BHB and RR Lyrae stars near the North Galactic Pole by means of radial velocities and GSC2 proper motions for which we were granted a GSC2 pilot-program. Furthermore, metallicities are estimated using the ΔS method.

Photometric and spectroscopic data were collected during the last years. A spectroscopic run was conducted in spring 2001, and two more are due in spring 2002 (SARG@TNG, LRS@TNG). First prelim-

inary results on the space motions show that our sample is distinctly retrograde.

1.1.4 The accreted component of the Galactic Halo: The Sagittarius Dwarf Spheroidal

Involved people at OAB: Bellazzini, Ferraro, Monaco.

There is now a growing body of observational evidences for an inhomogeneous Halo, where the tracks of the slow building up by hierarchical merging of subunits should be still observable and evident. The Sagittarius dwarf Spheroidal Galaxy (Sgr dSph) is the most evident and striking example of a *real time* accretion event occurring in the Galactic Halo. The main body of Sgr dSph orbits well within the Galactic spheroidal ($R_{GC} \simeq$16 kpc) and shows clear signs of being accreted and distrupted by the Galactic tidal field (e.g., Bellazzini, Ferraro & Buonanno 1999). Thus, the Sgr dSph is (and has been) one of the major contributors to the stellar content of the whole Galactic Halo.

In this framework, we have started a large photometric survey of this disrupting dSph. The final database will consist of V,I photometry and accurate astrometry for five 1deg fields, sampling different regions of the galaxy that is extended over a huge area of the sky. The data reduction is complete for a first field centered on the globular cluster M 54 (see Figure 1). The large database will provide the necessary insight for the study of the stellar populations and star formation history in this peculiar galaxy, as well as the basis for a detailed study of the chemical composition of its stars to be performed with VLT-FLAMES.

This research is in collaboration with Pancino (Dip. Astr. BO) and with the Trieste Observatory's group (Bonifacio, Molaro) within the ITAL-FLAMES consortium.

1.2 Globular Clusters

1.2.1 Observational tests of theoretical stellar models

Involved people at OAB: Bellazzini, Cacciari, Ferraro, Fusi Pecci, Greggio, Monaco, Origlia, Sabbi

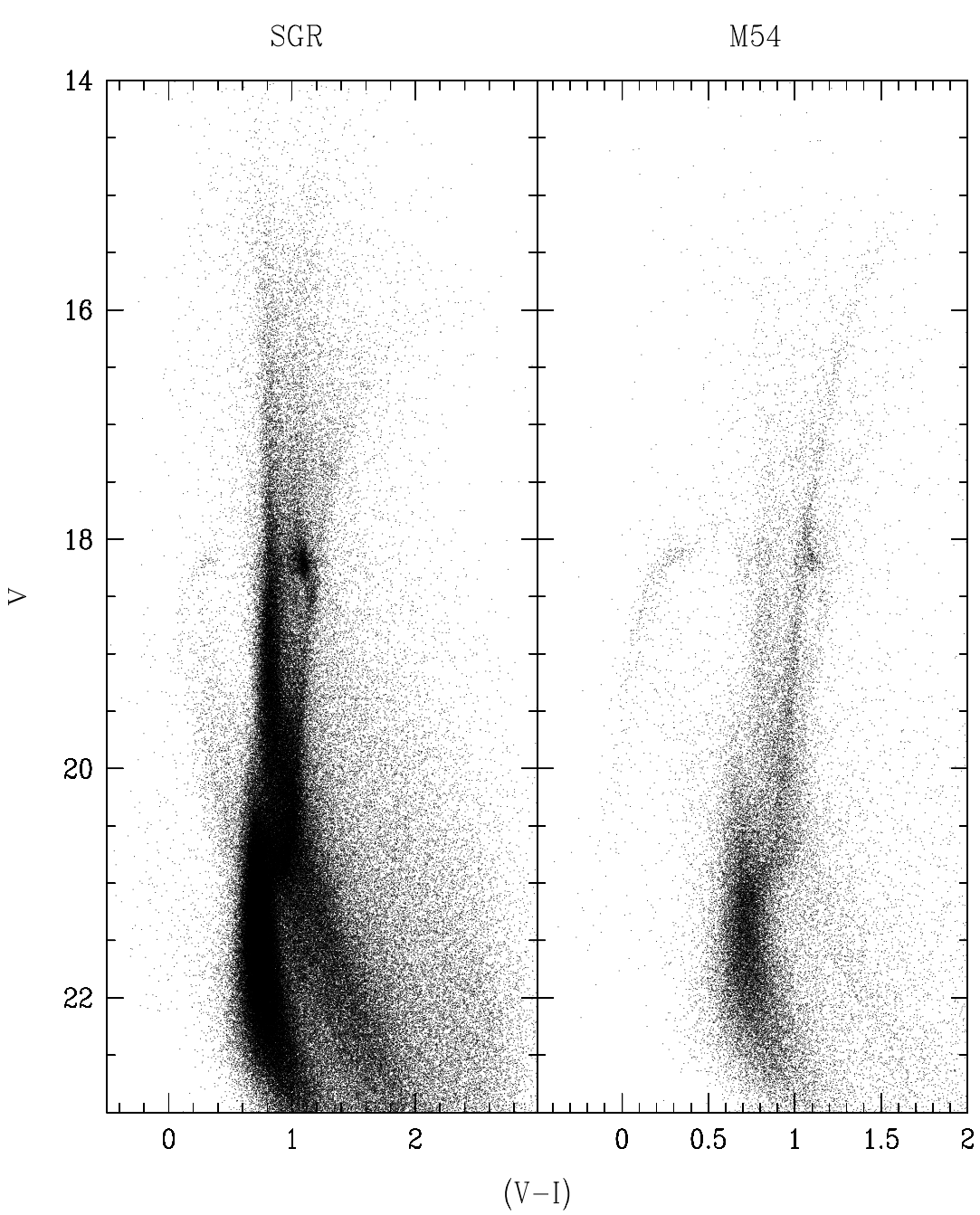


Figure 1: CMDs for the general field of the Sagittarius dwarf galaxy (left), and for a field centered on M 54 (right)

Stellar evolutionary models are often used to derive relevant properties of globular star clusters and galaxies, such as their age and metal content. The Luminosity Function of the stellar sequences in the CMDs, from the MS Turn Off (TO) up to the termination of the Asymptotic Giant Branch (AGB), has been recognized to be the most powerful instrument for testing stellar evolutionary models (in particular the accuracy of the input physics, the reliability of canonical assumptions, etc.).

A fully fruitful test requires that the observations be a) *complete*, b) *statistically significant*, and c) *accurate and adequate* for each specific evolutionary sequence. Point (a) means that virtually all the stars in a given area of the cluster are measured down to a given magnitude level, and that reliable corrections for incompleteness can be applied below that level. Point (b) means that observations should cover most of the cluster extension. Point (c) requires IR observations to measure the cool RGB stars and UV observations to properly study the blue sequences as the Horizontal Branch and the Blue Stragglers.

In this scenario the following main sub-projects represent a coordinated attack to the problem, in collaboration with Rood (University of Virginia, USA), and Catelan (Pontificia Universidad Catolica, Chile).

(a) Mass loss along the Red Giant Branch

Mass loss is well known to play an extremely important role in stellar evolution. In particular, the late stages of evolution of low– and intermediate–mass stars are strongly influenced by mass loss processes. Yet, our lack of knowledge on mass loss in cool RGB and AGB stars remains one of the most serious stumbling blocks for a comprehensive understanding of stellar evolution. In Galactic Globular Clusters (GGCs), theoretical models of HB and RGB stars imply that RGB stars *must* lose $\sim 0.2\,M_{\odot}$ prior to the HB phase; an additional $\sim 0.1\,M_{\odot}$ is then expected to be lost on the AGB, before the star evolves down to the white dwarf cooling curve. With the goal of studying the mass loss during the RGB evolutionary stage, a deep survey of the very central regions of six massive GCs has been made using ISOCAM in the 10 μm spectral region (Origlia et al. 2002, astro-ph/0201445). A significant sample of bright giants have an ISOCAM counterpart but only $< 20\%$ of these have a strong mid-IR excess indicative of dusty circumstellar envelopes. From a combined physical and statistical analysis we derived mass loss rates and frequency. We find that *i)* significant mass loss (at rates in the range

$10^{-7} < dM/dt < 10^{-6} M_{\odot}\,\mathrm{yr}^{-1}$) occurs only at the very end of the RGB evolutionary stage and is episodic, *ii)* the modulation timescales should be shorter than 1 million years, and *iii)* mass loss occurrence does not show a crucial dependence on the cluster metallicity. Our ISOCAM survey needs complementary deep, multicolor imaging at much higher spatial resolution to resolve the most crowded core regions of the clusters. A follow-up program using ground-based mid-IR facilities is in progress.

(b) The HB morphology

Conversely, we have used the HB morphology as a sort of magnifier of the mass-loss process occurring along the RGB. In this respect, a detailed analysis of the second parameter on the M 3 and Pal 3 cluster pair has been performed (Catelan, Ferraro & Rood 2001). The main result of this analysis is that the HB morphology of M 3 is significantly bluer in its inner regions than in the cluster outskirts, suggesting that the mass loss on the RGB has been more efficient in the inner than in the outer regions of the cluster. The comparison of the observed HB morphology with the theorethical models has shown that the different HB types of M 3 and Pal 3 can easily be accounted for by a small difference in age between the two clusters.

Another interesting result has been obtained in M 75 (Catelan et al. 2002), where a tri-modal HB has been discovered.

(c) The UV population in GGCs

Many new results are now supporting the claim that dynamical evolution of GGCs can affect their stellar populations. Schematically, both the integrated cluster colors and the properties of individual objects confirm the existence of dynamically induced variations in the evolution of many cluster members.

In this scenario, we have started a long term project which aims at using GGCs as a laboratory to study the impact of the (internal) environmental and (external) dynamical effects on the evolution of the cluster stellar population. We obtained UV-HST observations for this project, and are using UV data retrieved from the HST archive. The most interesting result this year comes from 47 Tuc: we have discovered (Ferraro et al. 2001) a large population of UV-excess stars (UVE) lying between the BSS sequence and the WD cooling sequence. This is the largest population of UVE stars ever detected in a GGG. If confirmed, we have finally found the long-searched-for population of interacting binaries predicted by the theory.

Further studies of NGC 288 have been conducted using HST data, revealing the presence of some very faint and blue stars that could be interpreted as Cataclismic Variables. VLT-FORS2 spectra of these stars have been taken and are presently being analysed and compared with the characteristics of redder stars in the same luminosity range.

(d) GC's as Simple Stellar Populations

Elliptical galaxies are a cornerstone in our understanding of the galaxy formation process in a cosmological frame. Two competing models exist for the formation of Ellipticals: the monolithic collapse and the more popular (multiple) merging of already formed units, as a natural result of hierarchical CDM models. A key point of interest in this framework is to derive the age and the metallicity of the bulk of the stars in ellipticals. The determination of these parameters, which for the vast majority of Es must rely on observations of their integrated light, is hampered by the problem of the age-metallicity degeneracy, and by the possibility of non-solar abundance ratios. The interpretation of the spectrophotometric properties of Es is generally made by comparing models of Simple Stellar Populations (single age and single metallicity assembly of stars, SSP) with the observations. In order to test and calibrate these models, we have collected spectra (ESO 1.5m) of globular clusters in the bulge of our galaxy, to be compared with the prediction of SSP models. The sample consists of 12 clusters, spanning a wide metallicity range and in particular extending up to solar metallicity. The two solar metallicity clusters in our sample also have a spectroscopically confirmed α-elements overabundance.

In 2001 we proceeded with the analysis of these data. In particular we find that the integrated spectral indices of these clusters do indeed confirm the idea that the central stellar populations in Es are enhanced in α elements, and that their total metallicity is super- solar. The comparison with current SSP models indicates the need to develop new models to correctly account for the effect of the overabundance. This work is in collaboration with Putzia and Saglia (Univ. of Munich), Kissler Patrick and Renzini (ESO), Maraston (MPE-Munich), Ortolani (Univ. of Padova).

1.2.2 Distances and ages of Galactic globular clusters

Involved people at OAB: Bellazzini, Bragaglia, Clementini, Ferraro, Fusi Pecci

(a) Relative ages

With our work, presented in Bellazzini et al. (2001c), we have performed an important test on the relative ages of three GC's (NGC 288, NGC 362 and NGC 1851) which, notwithstanding a very similar metal abundance, show extremely different HB morphologies. In particular, NGC 288 has an HB populated only blueward of the instability strip, while NGC 362 has only a red HB, similar to more metal-rich clusters. Making use of the bimodal HB in NGC 1851 we have performed a direct comparison of the relative ages of NGC 288 and NGC 362, not possible without this technique (*bridge test*).

The strength of our approach lies in the very homogeneous observational data set (same instrument, same observing run, same reduction method, and same calibration to the photometric standard system for the three GC's). In fact we have proven that past versions of this test were invalidated by the non homogeneous data sets used.

On the basis of our analysis, NGC 288 is shown to be ~ 2 Gyr older than NGC 362. A detailed comparison of the observed HB morphology with theoretical models (Catelan et al. 2001) permitted us to show that the different morphologies can be ascribed to this age difference; furthermore, it gave important indications of a possible correlation between stellar density in GC's and the amount of mass loss during the RGB phase.

(b) The White Dwarf Cooling sequence

OAB researchers have collaborated to an HST project which uses the *White Dwarf cooling sequence* to determine the distance to a sample of GCs. The goal was to reduce the uncertainty in distance and age to about 10 %, thus putting a significant lower limit to the age of the Universe.

After NGC 6752, the procedure was applied to 47 Tuc and a distance modulus of $(m - M)_V = 13.27 \pm 0.14$ and an age of 13 ± 2 Gyr were derived (Zoccali et al. 2001).

(c) The Main Sequence Fitting technique

Extensively applied in the eighties although affected by rather large error bars (± 0.25 mag in distances and ± 4 Gyr in ages) the GC Main Sequence Fitting technique derives distance from the comparison of the GC Main Sequence to a suitable "template" formed by metal-poor subdwarfs in the solar neighborhood, whose distances are accurately measured via trigonometric parallaxes. This method, one of the simplest and most robust techniques for deriving distances to GGCs, has

been substantially relived by the release of the Hipparcos trigonometric parallax catalogue in June 1997.

The Hipparcos based MSF technique has produced a "stretching" of the GC distances which definitely favors the *long astronomical distance scale*, and, in turn, the derivation of Galactic GCs *younger ages* by 2-3 Gyrs. The estimated lower limit for the age of the Universe derived from the absolute age of the Galactic GCs is 12.9 Gyr, with a residual uncertainty of $\pm$2.9 Gyr (Carretta et al. 2000). This uncertainty in the age mainly arises from a residual uncertainty of ($\pm$0.12 mag) in the GCs MSF distances which has two major contributors: (i) the reddening and (ii) the metallicity scales adopted for the field subdwarfs and the GC stars, with a statistical uncertainty of $\sim$ 0.07 mag from each source.

An ESO Large Programme (see Section 1.2.4) is presently carried out to reduce the residual uncertainty in the MSF distances down to $\pm$0.07 mag (i.e., an uncertainty dominated by the parallax error) and the corresponding errors in the GC ages to $\pm$1 Gyr, by addressing these effects. The abundance analysis of the NGC 6752, NGC 6397 and 47 Tuc stellar spectra has demonstrated that in these clusters the [Fe/H]'s obtained for the TO-stars agree perfectly (within a few per cents) with that obtained for stars at the base of the RGB (Gratton et al. 2001a) cutting down to $\sim$ 0.03 mag the uncertainty in the MSF distances due to the metallicity scale. The use of a reddening scale homogeneously derived for field and cluster dwarfs from $B-V$ and $b-y$ colours has allowed us to cut down to $\sim$ 0.04 mag the error contribution due to reddening scale. The new estimated *lower limit* for the age of the Universe derived from the absolute age of these 3 Galactic GCs is 13.1 Gyr, with a residual uncertainty of $\pm$1 Gyr (Gratton et al. 2002, in preparation).

(d) The Red Giant Branch Tip method

We have obtained the most accurate observational zero point for the calibration of the RGB Tip (TRGB) as distance indicator (Bellazzini, Ferraro & Pancino 2001b, see Figure 2). This calibration is based *i*) on the optimal detection of this observable in a sample of more than 220000 stars in the GC ω Cen (Pancino et al. 2000), and *ii*) on the geometric measure of the distance to this GC obtained by Thompson et al. (2001) using a *double-lined* eclipsing binary system, member of the cluster. This result leads to a new basis of the distance scale, *completely independent* of the classical idicators (RR Lyrae stars

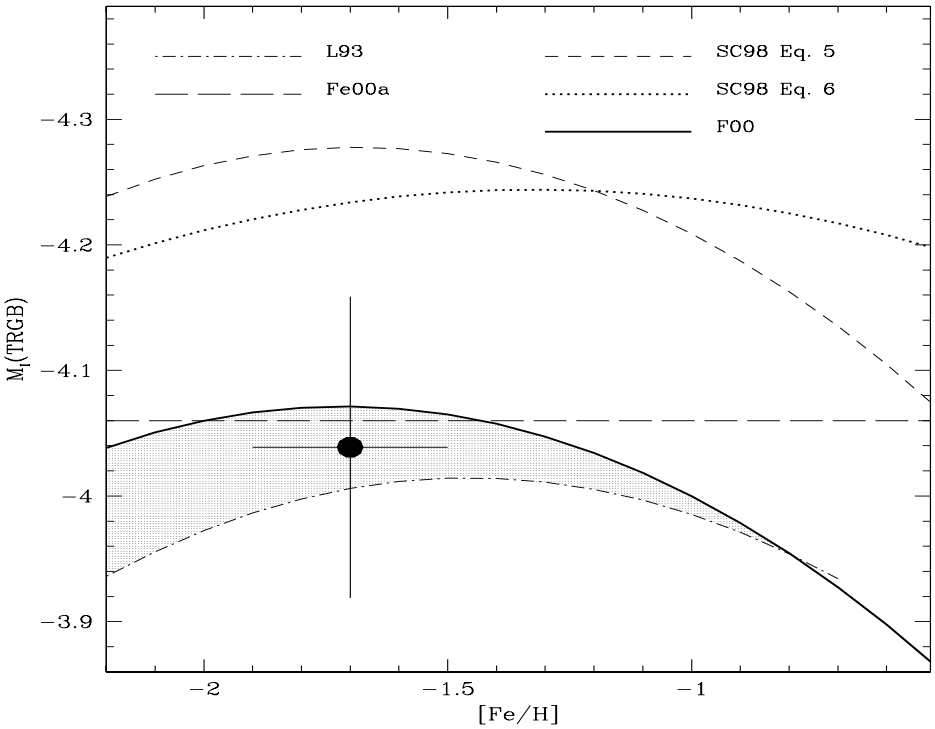


Figure 2: The absolute magnitude M_I of the TRGB in ω Cen, obtained by Bellazzini, Ferraro & Pancino (2001b) is here compared to previous empirical (LMF93, Fe00a, F00) and theoretical (SC98) calibrations. Our point represents the most robust and accurate measure of the TRGB absolute magnitude ever obtained, and is completely independent of the distance scales based on RR Lyrae's or Cepheids.

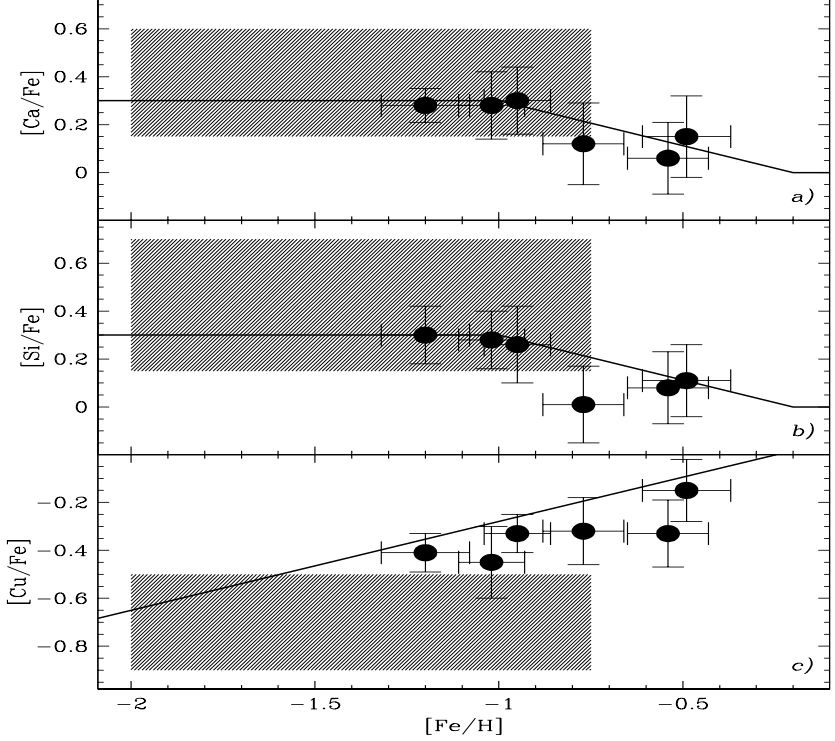


Figure 3: First evidence of SNe Ia enrichment in the metal rich giants of ω Cen (Pancino et al. 2002). Element ratios for [Ca/Fe] (*a*), [Si/Fe] (*b*) and [Cu/Fe] (*c* from high resolution VLT-UVES spectroscopy for 6 giants in ω Cen are shown. The shaded areas mark the region where previous, high resolution measurements for ω Cen giants lie and the solid lines represent the corresponding trends in our Galaxy.

and Cepheids).

This research is in collaboration with Pancino (Dip. Astr. BO).

1.2.3 ω Centauri

Involved people at OAB: Bellazzini, Ferraro, Origlia

ω Centauri is the largest, brightest cluster ($M = 4 \times 10^6 M_\odot$, Pryor & Meylan 1993) in the Galactic Halo, and it is the *only* GC which shows clear and undisputed variations in the chemical content of its stars. From this point of view, ω Cen could be considered a *bridge*

system between the genuine globulars, which are unable to retain the gas ejected by their former massive stars, and the dwarf galaxies, which are the least massive self-enriching stellar systems known.

We started a long-term project aimed at performing a detailed photometric and spectroscopic study of the stellar population in ω Cen. This project is one of the major pilot project of the OAB stellar group. The first surprising result was the discovery of a distinct anomalous RGB (RGB-a), previously unknown, significantly redder than the bulk of the normal RGB stars (Pancino et al. 2000).

Starting from this first result, we are undertaking national and international collaborations in a coordinated photometric and spectroscopic effort aimed at finally solving the mistery of the stellar content in this surprising cluster. We are using the instrumentation available at ESO, on board of HST and at other international telescopes. A spectroscopic screening of the multi-populations of red giants in ω Centauri by means of high resolution echelle spectra with UVES@VLT and medium-resolution infrared spectra with SOFI@NTT of more than 40 stars is in progress. The major results obtained so far (Pancino et al. 2002) by analyzing a first sample of 6 stars can be summarized as follows: (1) We confirmed the existence of three major metallicity regimes: metal-poor at [Fe/H]=-1.6$\pm$0.2 dex, intermediate at [Fe/H]=-1.2$\pm$0.2 dex and the RGB-a at [Fe/H]$>= -0.8$. (2) The metal-poor and intermediate populations show (as expected) a substantial α-enhancement, which indicates an enrichment of the interstellar medium by type II SNe on a relative short time-scale, before the onset of type I SNe. The RGB-a population, on the contrary, is poorly α-enhanced, suggesting a significant iron pollution of the interstellar medium by type I SN ejecta (see Figure 3). Such a different chemical signature between the RGB-a and the other cluster stars indicate that *stars belonging to the anomalous branch had a very different evolutionary history with respect to the other stars of ω Centauri.*

This can be explained either by *(i)* a self-enrichment scenario, implying a more continuum star formation process as well as some age spread or by *(ii)* a merging scenario in which the main body of the cluster accreted the metal-rich sub-system.

In order to investigate whether an age spead exists among the various sub-component, we are planning to measure relative ages by obtaining: (a) high resolution UVES@VLT spectroscopy of a sample of Sub-Giant Branch (SGB) [6 SGB's have been observed in April 2002] and (b) high precision FORS@VLT photometry of the central

regions of the clusters [these observations have been obtained in 2001, Period 68]. The entire data set will allow us to disentangle age and metallicity effects and to finally derive the star formation history of this surprising cluster.

This research is in collaboration with Pancino (Dip. Astr. BO) and Pasquini (ESO) and many more.

1.2.4 Abundances in Globular Clusters

(a) Halo Globular Clusters

Stars in each GC, with the exception of ω Cen and possibly of M 22, have generally very homogenous composition as far as Fe-peak elements and α-elements are considered, while abundances of lighter elements (from C to Al) show a complex, not yet fully explained, pattern (i.e., CN-CH band strength anticorrelation, Na-O anticorrelation, etc.) not seen in field stars. Proposed explanations have varied from an *in situ* mechanism (e.g., very deep mixing of nuclear-processed material) to an external source of material (either primordial protocluster gas or processed material from a polluting companion). Both explanations could work for RGB stars, while main sequence stars require the second one.

(i) Abundances along the RGB

Involved people at OAB: Bragaglia, Bellazzini, Ferraro, Monaco.

In the framework of a large programme in collaboration with researchers in Padova and Roma, we aim at deriving accurate abundance measures for a representative number of giants in a GGC sample by using the multiplex FLAMES facility at the VLT (UVES + GIRAFFE). Our first target has been M 22, since there are reasons to believe that M 22 could have a significant dispersion in the metallicity of red giants. Even if the effect is going to be smaller than in ω Cen, the detection of such a spread in metallicity would indicate that at least another globular cluster in our Galaxy has experienced the same kind of chemical enrichment history as ω Cen. Such a discovery would be of invaluable help in understanding the mechanism of formation of ω Cen and would shed light on the processes that are at the basis of the halo formation and evolution. We have already secured a set of high resolution UVES spectra for 8 giants in this cluster during an observing run in April 2002.

This work is in collaboration with Pancino (Dip. Astr. BO).

(ii) Abundances of Main Sequence Turn Off stars

Involved people at OAB: Bragaglia, Clementini

Only recently stars near the main sequence Turn-Off (MSTO) have become observable at the necessary S/N and resolution. As part of an ESO Large Programme (PI Gratton), we have acquired with UVES@VLT in 2000 and 2001 (24 nights in total) high resolution spectra (R$\geq$ 40000) of a large number of stars at the main sequence turn-off and at the base of the sub-giant branch in NGC 6752, NGC 6397, 47 Tuc, NGC 6809 and NGC 7099 (analysis completed only for the first two).

The [Fe/H] abundances determined for NGC 6752 and NGC 6397 (identical for MSTO and subgiant stars: Gratton et al. 2001a,b,c,d, 2002) have removed one of the possible major sources of uncertainty claimed to affect the MSF distances (see Section 1.2.2). Our analysis has also put a strong constraint on sedimentation.

Furthermore, we have found presence of O-Na and Mg-Al anticorrelations in MSTO stars in NGC 6752, but not in NGC 6397, hence ruling out internal mixing as the cause of such anomalies. Finally, we have studied Li abundances, and found that MSTO stars in NGC 6397 (and O-rich ones in NGC 6752) have Li abundances very close to the Spite plateau value, supporting the primordial origin of lithium in metal-poor stars (Bonifacio et al. 2002, submitted to A&A).

This work is in collaboration with Gratton and Carretta (Padova Obs.), Bonifacio (Trieste Obs.), Pasquini (ESO), and many more (see list of publications).

(b) Bulge Globular Clusters

Involved people at OAB: Ferraro, Origlia.

Bulge GCs are a fundamental stellar population of our Galaxy and it is most interesting to compare their detailed compositions with the Galactic bulge field population (McWilliam & Rich 1994). For many of these bulge clusters, foreground extinction is so large as to preclude optical studies of any kind, particularly at high spectral resolution. In the last few years we have undertaken a long term project devoted to study a representative sample of Bulge globular clusters in the IR. Using the SOFI medium-resolution imager/spectrograph at ESO/NTT and the NIRSPEC high-resolution echelle spectrograph at Keck II, we have secured high quality photometry and infrared spectra of 10 globular clusters in the Bulge. Other observing time at KeckII has been assigned to this program in the next months. The spec-

tral synthesis analysis is in progress and a first paper with the results on Liller 1 and NGC 6553 has been recently published (Origlia, Rich & Castro 2002, astro-ph/0112104). We find [Fe/H] $= -0.3 \pm 0.2$ and [O/H] $= +0.3 \pm 0.1$ (from the OH lines) for the giants in both clusters. We measure strong lines for the α-elements Mg, Ca, and Si, but the lower sensitivity of these lines to abundance permits us only to state a general [α/Fe] $= +0.3 \pm 0.2$ dex. The composition of the clusters is similar to that of bulge field stars and is consistent with a scenario in which the clusters formed early, with rapid enrichment.

This reasearch is in collaboration with Rich (UCLA, USA).

1.2.5 The Globular Cluster System of the Andromeda galaxy

Involved people at OAB: Bellazzini, Cacciari, Federici, Fusi Pecci, Parmeggiani.

The M31 cluster system is the largest sample of GC's found in the Local Group, negligibly affected by reddening, at least for a large outer sub-set, and sufficiently close to allow individual stellar observations. M31 offers the unique opportunity of studying the GC system of a spiral galaxy similar to (albeit larger than) the Milky Way in very good detail and without some of the limitations that affect the Galactic GC system. The OAB M31 team, in collaboration with Marano (Dip. Astr. BO) and scientists of other italian and foreign institutions, is studying the globular clusters in M31 and other galaxies of the Local Group using both photometry (from the UV to the IR bands) and spectroscopy. The scope of the program is to utilize the globular cluster systems to improve our knowledge on the mass, dynamics and chemical evolution of the parent galaxies, and as secondary distance indicators and stellar population templates.

A sample of 19 confirmed GCs in M31 has been observed with WFPC2-HST with the aim of comparing the stellar population of the M31 and Milky Way cluster systems, and measuring the dependence on metallicity of the HB luminosity for a sample of clusters at the same distance. The CMDs reach at least one magnitude fainter than the Horizontal Branch level, and their analysis shows that M31 GCs are very similar to the Milky Way globular clusters, and that there is no strong indication of an intermediate age population of GCs analogous to those found (for example) in the SMC. Preliminary results have been presented at international conferences (Rich et al. 2002).

Finally, we are preparing a comprehensive, homogeneous revised catalog of all morphological, spectrophotometric, astrometric and kinematic data for the clusters and the cluster candidates in M31.

As a bonus of the HST pointings which have M31 GC's as primary targets, we have obtained a wide photometric survey, sampling the disk and the halo of M31 toward 16 different lines of sight. The CMDs obtained show that descending red giant branches, indicative of high metallicity, persist even at 30 kpc from the nucleus. Metallicities have been estimated by comparison to template globular cluster giant branches of known metallicity.

1.2.6 Globular Cluster Systems in external galaxies

Involved people at OAB: Cacciari, Federici.

Spectroscopy of extragalactic globular clusters provides a wealth of information on the formation and the evolution of their parent galaxies. The aim of this project, in collaboration with Held (Padova Obs.) and Testa (Roma Obs.), is to study the globular cluster systems in galaxies of different morphological types (E/S0 and spirals), in order to investigate the existence of stellar sub-populations with different chemical and/or dynamical characteristics, to estimate the galaxy mass and to probe the existence and estimate the mass of dark matter haloes.

We have secured EMMI@NTT multi-slit spectroscopy for 40 known GCs in the inner regions of NGC 5128, the nearest giant elliptical galaxy, and deep MOS spectroscopy using FORS1@VLT of about 30 GCs in the Sombrero galaxy (NGC 4594), an early-type spiral with a dominant bulge. Most of the clusters in NGC 5128 are similar in age to the Galactic globulars, and their metallicity distribution is clearly bimodal, thus confirming the presence of two cluster populations (Held et al. 2002). The spectra of the globular clusters of NGC 4594 have been completely reduced and are currently being analyzed.

Since efficient spectroscopic observations require previous identification of bona-fide globular cluster candidates, and in preparation for a systematic spectroscopic study at the VLT with FLAMES or VIMOS, we have undertaken a wide-field multicolor imaging survey of galaxies of different morphological types (E/S0) as far as the Virgo cluster: NGC 3115, NGC 4526, NGC 4406, NGC 253, NGC 5128, NGC 4594.

1.3 Nearby Galaxies

1.3.1 Magellanic Cloud clusters

Involved people at OAB: Ferraro, Origlia

The spectral evolution of a Simple Stellar Population (SSP) and its most evident colour glitches are ideal *clocks* for dating primeval galaxies and deriving a suitable, empirical relation between look back time and redshift. Deriving the age of a stellar population implies: (1) the selection of a suitable clock (this requires an accurate time calibration of *the stellar evolution*), (2) the actual reading of the age (this requires an accurate estimate of the global metallicity of the SSP, since the stellar clock is extremely sensitive to the chemical composition – the so-called age/metallicity degeneracy.

The empirical calibration of the clock which settles the spectral evolution of SSPs and its readability are the primary goals of our project. The globular cluster system of the Magellanic Clouds (MC) provides an unique opportunity to investigate the integrated spectrophotometric behaviour of stellar populations as function of both age and chemical composition. We are tackling these major astrophysical objectives by means of a coordinated spectrophotometric survey on a representative sample of MC clusters, aimed at determining with great accuracy and in a homogeneous way their age, metallicity and overall integrated spectral properties. During two runs with SOFI@NTT in January 2000 and December 2001, our group secured high quality J,H,K photometry of 20 LMC clusters spanning the age range between $\sim$50 Myr and a few Gyr. Popolous and complete near-IR CMDs covering all the RGB extension have been obtained. The high quality and homogeneity of such an IR database will provide the most accurate empirical determination of the occurrence of the so-called AGB and RGB phase transitions and their contribution to the cluster integrated light in each photometric IR band–pass and in bolometric. These empirical estimates compared to those of the models will allow to calibrate the integrated magnitude and colour glitches in terms of age, i.e., to reliably calibrate the stellar clock which is the fundamental engine of any evolutionary synthesis technique.

The correct reading of the age from a SSP requires the accurate knowledge of the global metallicity. This major piece of information is still lacking, namely a self-consistent metallicity scale and a detailed description of the abundance patterns of MC clusters. In order to

fill such a gap, we started a spectroscopic survey at medium-high resolution in the visual and in the IR for a representative sample of MC clusters. Such high quality spectroscopic data coupled with the photometric database secured by our group over the last 10 years will allow to calibrate the *evolutionary clock*, a fundamental tool to trace the history of star formation and evolution of primordial galaxies.

This research is in collaboration with Testa (Roma Obs.) and Maraston (Sternwarte, München, Germany).

1.3.2 Dwarf spheroidal galaxies

Involved people at OAB: Bellazzini, Ferraro, Origlia, Sabbi

The Local Group (LG) of Galaxies is a unique laboratory to study the properties of the most common types of galaxies in the Universe. Moreover, it offers the opportunity to calibrate the luminosities of *standard candles* – such as Cepheids and RR Lyraes – which can be used to determine the extragalactic distance scale, hence the value of H_0 and the age of the Universe.

In this context we started a large programme specifically devoted to collect wide-field images in a sample of Dwarf Spheroidal galaxies in the Local Group, (using the WFI@2.2m in the Southern emisphere and a mosaic of fields with LRS@TNG for Northern galaxies), with the aim of studying the evolved stellar population in these galaxies and deriving homogeneous distance moduli.

A first important result has been obtained for the dwarf spheroidal galaxy Sextans, where we have studied the evolved population using WFI@2.2m. For the first time the presence of two distinct stellar populations of different metallicities has been revealed in this galaxy (Bellazzini, Ferraro & Pancino 2001a).

Our group is presently working on a detailed and independent reassessment of the distance scale to Local Group galaxies, based on the new calibration that we obtained for the TRGB (see Section 1.2.1). The necessary homogeneous dataset comes from a Large Programme at the TNG: we are observing all the Northern members of the Local Group in V and I, and a subsample of them in the near infrared with NICS (12 nights have been assigned to this project in 2001). We obtained deep photometry for a number of dwarf galaxies (Leo I, Leo II, Leo A, Draco, Ursa Minor) and the data reduction has been completed for four of them. We extended the survey to the M31 satellites

and the collected sample will provide revised distances to 16 galaxies of the Local Group, as well as a comparative study of their evolved stellar populations.

This research is in collaboration with Pancino (Dip. Astr. BO) and Oliva (TNG).

1.3.3 Star formation histories in late–type dwarf galaxies

Involved people at OAB: Bellazzini, Greggio, Origlia, Parmeggiani, Tosi.

Late–type dwarf galaxies are playing an increasingly central role in understanding galaxy evolution, because their proximity allows one to examine in detail important issues, like the occurrence of galactic winds, the chemical enrichment of the interstellar and intergalactic media, the photometric evolution of galaxies. Besides, their low level of evolution, as implied by the low metallicity and the high gas content, makes these systems the most similar to primeval galaxies and, therefore, the most useful to infer the primordial galaxy conditions. Furthermore, they have been suggested to represent the building blocks of larger galaxies. Understanding how late-type dwarfs evolve and what were their conditions at early epochs is then crucial also for cosmological purposes. It is thus fundamental to derive the star formation history (SFH) in a number of representative systems of the major morphological sub-classes: blue compact galaxies, dwarf irregulars, giant irregulars (Tosi 2001b). To this aim we are undertaking a long term project (in collaboration with Aloisi, Clampin, Leitherer and Nota, Baltimore, USA) to study, from deep and accurate photometric data (ESO-VLT and HST), the stellar populations of a number of dwarfs known to show evidence of galactic winds. So far we have sampled IZw18, NGC 1569 and NGC 1705. HST-ACS time has been allocated to observe SBS1415+437. The resolved stars allow us to derive the intensity as a function of time of the star formation activity and the IMF of these galaxies back to fairly old epochs with the method of synthetic CMDs pioneered by our group and amply tested and applied by the international community.

In June 2001, the international workshop on *Observed HR diagrams and stellar evolution: the interplay between observational constraints and theory*, held in Coimbra (Portugal) has provided the opportunity to compare the results of the synthetic CMD method obtained by our

group with those obtained by all the other groups active in this field. All the groups had to derive, with their own procedures, the SFH of an LMC field observed with HST-WFPC2, whose resulting CMD was provided to all groups together with all the information on the photometric errors and incompleteness of the data (Tosi et al 2002a). A *blind* comparison (see Gallart & Skillman 2002) has demonstrated that, despite fairly different approaches, the method provides results consistent with each other within a factor of two. When critical arguments are considered, even better agreement is reached.

The procedure of deriving the SFH from synthetic CMDs is ultimately based on the relation between the mass of the stellar populations and the number of stars counted on the CMD. The connection between the total mass in stars and the star counts in various regions of the CMD has been investigated from a purely theoretical point of view (Greggio 2002), to the end of providing basic relations between the mass in stars and the stars' counts for stellar populations with an age spread. It is found that the bright portion of the CMD allows to recover the star formation history with a fair degree of detail up to look back times of approximately 0.3 Gyr. For older stellar populations, the counts in selected regions of the CMD (RGB, He burning clump, Bright AGB) make it possible to estimate the mass in stars within a factor of 3, for an adopted Initial Mass Function slope.

In 2001 we completed the analysis of the red stellar populations in NGC 1569, by analyzing both the field (Aloisi et al. 2001) and the stellar cluster (Origlia et al. 2001) populations. We found a complex stellar population, covering the whole age range from a few Myr to a Hubble time. The intensity of the most recent SF activity is somewhat higher than in the past and mainly concentrated around the super star clusters, while the older stellar populations have a more uniform distribution within the galaxy.

We also completed the analysis of the HST-WFPC2 and HST-Nicmos VIJH data on NGC 1705 (Tosi et al. 2001). These data have allowed us to derive its distance with great accuracy from the red giant branch tip, and to show that this blue compact galaxy has a large fraction of old stars (hence has been strongly active also in remote epochs) and has a population age gradient, with decreasing age for decreasing galactocentric distance. We have started to apply the synthetic CMD method to concentric regions from the galaxy center to study their SFHs (Annibali et al. 2001a, 2001b).

Within the collaboration with Schulte-Ladbeck (Univ. of Pitts-

burg) and Hopp (Univ. of Munich), we have completed the analysis of HST data of Leo A and NGC 4214 (Drozdovky et al. 2002, Schulte-Ladbeck et al. 2002). In both cases we detect a considerable fraction of old stars, and a centrally concentrated young/ intermediate age component. These cases add to the numerous other examples of dwarf galaxies which experienced star formation since the very early epochs. The results are currently under publication on the Astronomical Journal

Numerical chemical evolution models have been computed (Recchi et al. 2002) for the blue compact galaxy IZw18, based on the SFHs derived by us (Aloisi et al. 1999) applying the synthetic CMD method to HST data. These new generation models take into account the effects of the supernovae explosions on the hydrodynamics of their interstellar medium and the possible onset of galactic winds. Analogous models will be applied in the future to NGC 1705 and the other late-type dwarfs analyzed with our method.

1.4 RR Lyrae variable stars

RR Lyrae's have long been recognized to be excellent tracers of old stellar populations, as well as primary distance indicators for Population II systems. Being primary distance indicators in the Galaxy and in the Magellanic Clouds, RR Lyr's are cornerstones of cosmological distance and time scales.

The absolute magnitude of the RR Lyrae's $M_V(RR)$ is known to depend on metallicity: $M_V(RR)=\alpha\times$ [Fe/H] + β. However, there is no agreement either on the zero-point β or on the slope α of this relation, since $\beta \sim 0.5$ or 0.75 mag (at [Fe/H]$=-1.5$) in the *long* and *short* distance scales, respectively, and literature values for α range from 0.30 mag/dex to 0.18-0.20 mag/dex.

RR Lyrae stars and their role in establishing the astronomical distance scale have been a major field of study at the OAB since 1984 (e.g. Cacciari et al. 1987). At present, several research programs at various levels of completion are being carried out.

1.4.1 β from the Baade-Wesselink method

Involved people at OAB: Cacciari, Clementini.

The Baade-Wesselink determination of the absolute luminosity of the galactic field RR Lyrae variables is currently being revised in order to test the effects on this technique of the most recent model atmospheres with various approximations in the treatment of convection, different values of turbulent velocity and more complete and accurate opacity tables, as well as the use of the instantaneous gravity along the pulsation cycle (Cacciari et al. 2000). In May 2001 we have obtained with SARG@TNG high resolution spectra of a few RR Lyrae in the GGC M 3, to derive accurate radial velocity curves. Along with IR (K-band) ARNICA data taken in a previous run at the TNG, this database will be used to apply the B-W method directly on RR Lyraes in this very interesting GC. The very few previous studies of this type, that date back to about 10 years ago, did not produce reliable results due to the poor quality of the data, obtained with smaller telescopes and less powerful detectors.

1.4.2 α from ΔS analysis of RR Lyrae stars in the bar of the LMC

Involved people at OAB: Bragaglia, Clementini, Di Fabrizio.

The slope of the luminosity-metallicity relation followed by RR Lyr's can be directly measured using a population of RR Lyrae variables all at the same distance, and spanning a suitable range in metal abundance. *RR Lyrae's in the Large Magellanic Cloud (LMC) bar* play a key role in this respect, since they can be considered at the same distance from us, are very numerous, and span about 1 dex in metallicity. The slope of the luminosity-metallicity relation for RR Lyrae stars is being investigated in collaboration with Carretta and Gratton (Padova Obs.).

In December 2001 we have obtained low resolution spectroscopy with FORS1@VLT for 100 RR Lyrae at minimum light and 350 clump stars in the bar of the LMC. Examples of some reduced spectra are shown in Figure 4. These spectroscopic data will allow us to measure metallicities accurate to $\sim$ 0.15-0.20 dex for both RR Lyr's (from the ΔS index, Preston 1959) and clump stars. The RR Lyrae metal abundances coupled with high quality photometry by Clementini et al. 2001a (see Section 1.4.3) will permit us to define α to better than 0.05 mag/dex, thus providing a clearcut choice between the steep and mild slopes proposed for the RR Lyrae luminosity-metallicity relation.

The metal distribution for a conspicuous number of LMC red clump stars will be used to address the controversial issue of the red clump absolute magnitude dependence on chemical composition, which so far limits its use as a distance indicator.

1.4.3 Distance to the Large Magellanic Cloud

Involved people at OAB: Bragaglia, Clementini, Di Fabrizio.

The luminosity, the mass-metallicity dependence for RR Lyrae variables, and the luminosity of the clump stars in the bar of the LMC and their role in measuring distances are being investigated, in collaboration with Carretta and Gratton (Padova Obs.), and Marconi (Napoli Obs.).

B and V light curves have been obtained for 130 RR Lyraes, and ΔS metallicities have been derived for 6 double-mode (RRd) pulsators

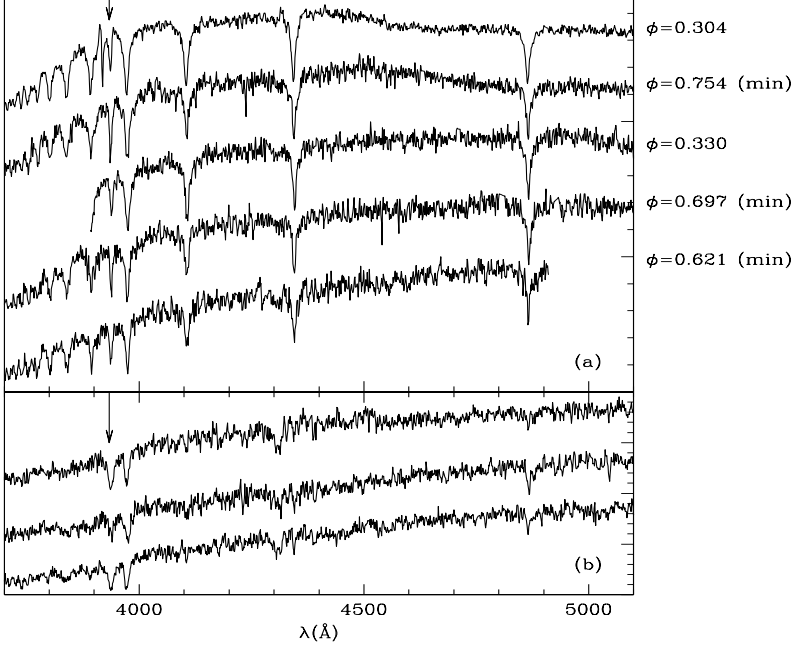


Figure 4: Spectra of RR Lyrae's and clump stars in the bar of the LMC, obtained with FORS1@VLT.

in the sample (average metallicity: [Fe/H]$=-1.5 \pm 0.2$). These metal abundances coupled with mass determinations from pulsational models purposely computed and the Petersen diagram are used to compare the mass-metallicity distribution of field and cluster variables. Field and cluster RRd's are found to follow the same mass-metallicity distribution, strengthening the case for uniformity of properties between field and cluster variables (Bragaglia et al. 2001b).

New BVI photometry in extremely good seeing and photometric conditions has been obtained for this project at the 1.5m Danish telescope in January 2001. The global pulsational properties of the sample as well as a very accurate estimate of the average apparent luminosity of the LMC RR Lyrae's and of the clump stars, have been obtained from the photometric data. An independent estimate of the LMC reddening was obtained from the colors of the edges of the instability strip defined by the RR Lyrae in our sample. Our findings have been compared to previous results in literature. In particular, we have done a straightforward comparison with OGLE photometry for the LMC clump stars, with fundamental bearings upon the *short* and

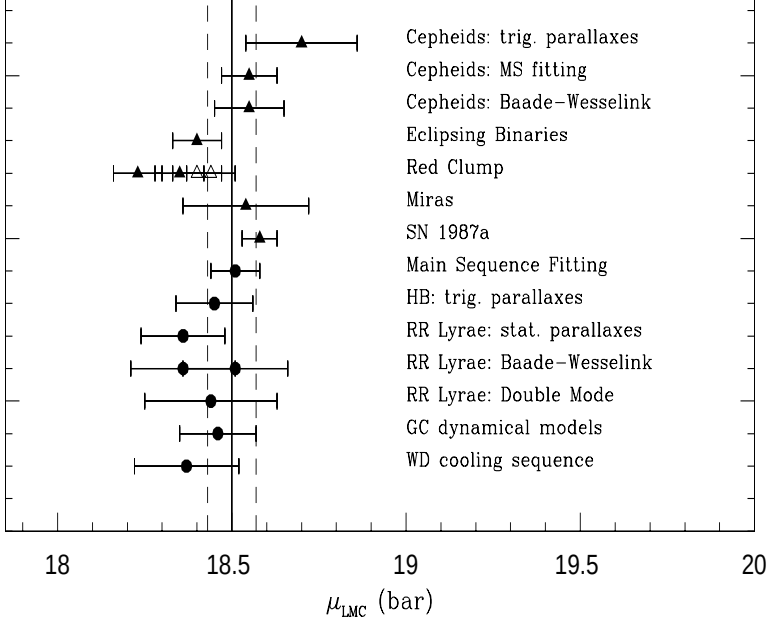


Figure 5: Distance moduli to the LMC obtained from Population I (triangles) and Population II (circles) distance indicators (from Clementini et al. 2001a, astro-ph/0004771)

long distance scale controversy (see Clementini et al. 2001a, astro-ph/0004771, M. Maio "Laurea" thesis, and Figure 5). The addition of the new data points has allowed a much improved refinement of the light curves and of the derived periods and epochs of the RR Lyrae variables (Di Fabrizio et al., in preparation).

1.4.4 RR Lyrae in Local Group galaxies

Involved people at OAB: Baldacci, Clementini, Di Fabrizio.

The key role of RR Lyrae stars as tracers of the oldest population (and therefore of the epoch of galaxy formation) in resolved Local Group galaxies has been confirmed by their discovery in several LG dwarfs. By comparing the properties of RR Lyr's in nearby galaxies with those of the Milky Way variables, the metallicity and age of the oldest population can be estimated.

A search for RR Lyrae variables in the Local Group Galaxies (Leo I, NGC 6822, Phoenix, Fornax) in collaboration with Held, Saviane, Momany and Rizzi (Padova Obs.) and Poretti (Milano Obs.) is be-

ing carried out. Based on multicolour WFI@2.2m and FORS1@VLT time series photometry, RR Lyrae and anomalous Cepheids have been detected for the first time in Leo I (Held et al. 2001), and NGC 6822 (Clementini et al., in preparation), thus providing unambiguous evidence for the presence of old metal-poor stars all the way to the innermost regions of these composite stellar systems, and opening the possibility to derive accurate distances to these galaxies via these primary distance indicators.

A deeper search for variables in Leo I, NGC 6822, Phoenix and Fornax is being carried out using the Optimal Image Subtraction Method package ISIS2.1 (Alard 2000).

1.4.5 RR Lyrae in globular clusters

Involved people at OAB: Bellazzini, Cacciari, Clementini, Federici.

A successful search for candidate RR Lyrae stars in four GCs of the Andromeda galaxy has been completed using HST archival data (Clementini et al. 2001b).

A reanalysis of the properties of RR Lyr's in the Sgr GC M 54 has been undertaken, using BVI photometric data obtained in 1999. The main results include the clear identification of multiple stellar populations in Sgr and the re-classification of M 54 as intermediate in the Oosterhoff groups, thanks to the improved photometric quality of our data and the much larger number of variable stars that could be detected. Fourier analysis of the light curves is presently being performed, in order to estimate the physical parameters of the variables.

The search for RR Lyrae variables was extended to the metal-rich GC NGC 6304 and the metal-poor Sgr cluster Arp 2. In both cases the sample of candidate variables has been more than doubled, and the characteristics of these stars have been derived. High quality BVI photometric observations were taken in November 2001 of the clusters NGC 362 and NGC 1904 for a detailed study of their RR Lyr's and the second-parameter effect.

A very detailed analysis of the RR Lyrae stars in M3 is presently being performed in collaboration with Corwin (Univ. of North Carolina). Mostly based on Fourier decomposition of the light curves, this study is showing the impact and characteristics of the Blazhko stars, the presence of a good number of evolved stars and their properties, as well as the characteristics of the main variable star population.

1.4.6 Anomalous RR Lyrae

Involved people at OAB: Bragaglia, Clementini, Merighi, Tosi, Di Fabrizio

The photometric and high resolution spectroscopic study of a sample of RR Lyrae which exhibit anomalous scatter and large amplitude variations of their light curves is continuing, in collaboration with Carretta and Gratton (Padova Obs.), Ivans and Sneden (Univ. Texas), Marconi (Napoli Obs.), Smith (MSU), and Wilhelm (Southwestern Un.). The observational campaign conducted with the 1.52m telescope in Loiano, the 60 cm of the Michigan State University, the 40 cm of the Southwestern University, and the 2.7 m telescope of the McDonald Observatory (for spectroscopy) has been completed as well as the data reduction. CM Leo has been found to be a very regular *c*-type RR Lyrae with metal abundance [Fe/H]=-1.94±0.2. The photometric and radial velocity curves of CM Leo have been compared with the prediction of convective pulsational models getting an absolute magnitude M_V=0.47. This value, once corrected for evolutionary and metallicity effects, leads to a true distance modulus of the Large Magellanic Cloud of μ_0=18.43 mag.

1.5 Eclipsing binaries

Involved people at OAB: Bonifazi, Lolli.

The aim of the work is to increase the database of the fundamental stellar parameters and to test stellar structure and evolution. For this purpose, photometric observations of many binary systems have been collected at various telescopes (60 cm and 152 cm in Loiano and the 6m BAT of SAO in Russia) in order to derive their light curves. In addition, many data have been collected for precise timing of the light minima of systems exibiting apsidal motion (DR Vul, V380 Cyg, RR Lyn, AK Her, ER Vul, BF Aur) whose determination can be correlated to the mass distribution in the stellar interiors.

With the 152 cm telescope in Loiano - equipped with the Two-heads photometer - we collected the light curves of two W UMa-type systems XY Leo and RW Com. With the same telescope (together with the 6m BAT, that collected also some spectra) we observed the very interesting PCV NN Serpentis.

The light curve analyses are performed adopting computer codes (Wilson-Devinney, WINK, EBOPC) based on geometric and physical models which account for the various effects acting on the systems components.

In the year 2001 our work has proceeded: a) implementing the Wilson-Price computer program (Barone et al. 1988) in the Windows environment, operating a new CPU (AMD Athlon XP 1800+) which reduces the computing time down to 10 percent with respect to a VMS VAXstat 4000/90. This code is based on the Wilson-Devinney (1971) model, but its fitting procedure is based on the "controlled random search" (Price 1976); b) testing the code in two ways: solving light curves whose parameters were already obtained through the "classical" Wilson-Devinney code and solving light curves synthesized from a set of parameters. In both situations our results are very satisfactory.

We have also undertaken the analysis of our light curve of the W Uma-type spotted system RW Com.

This work is in collaboration with Guarnieri, Bartolini, Piccioni and Cosentino (Univ. Bologna), Beskin (SAO), Milano (Univ. Napoli) and Barone (Univ. Salerno).

1.6 Planetary Nebulae

Involved people at OAB: Stanghellini

1.6.1 Extragalactic Planetary Nebulae

The program on the Magellanic Cloud Planetary nebula (PN) continues to produce results. This project is a major effort started in 1997, to understand PN evolution in different environments. In collaboration with Shaw (NOAO),Blades, and Mutchler (STScI), and Balick (U. of Washington), a series of observing programs to probe PN morphology in extra-galactic environments have been successfully executed. The analysis also include HST Data Archived images.

We have observed about 30 LMC PNe with an innovative method involving slitless STIS/HST spectroscopy, capable of revealing the morphology of LMC PNe in all the major optical recombination and forbidden lines. We obtained the largest sample of extragalactic PN morphology ever observed with this much detail. A first set of images has been published in a STScI press release, and presented at international meetings. An invited review on this subject was given at the

Planetary Nebula IAU Symposium in November 2001. Three refereed papers have been published on this subject, and several others are in preparation. An invited science highlight article in the Annual Report for the Space Telescope Science Institute was written on this results. The early science results from this study can be summarized as follows:

i) The LMC morphological types are similar to their Galactic counterparts. Nonetheless, the ratio of symmetric-to-asymmetric PNe is higher in the Galaxy than in the LMC. Future completion of the LMC sample will allow a sound comparison between the two samples, to confirm the important conclusion that morphology is related to the metallicity of the population. We also show that the surface brightness of LMC PNe declines with physical photometric radius, as expected, and that the asymmetric PNe are typically low surface brightness objects. Given that all LMC PNe are at approximately the same distance from us, we can infer that the dynamic evolution also depends on morphological type.

ii) The LMC PN morphology correlates tightly with the progenitor abundance of elements that are not affected by stellar evolution (e.g., Ne, S, Ar). This finding bears on the question of formation mechanisms for asymmetric PNe: the genesis of PNe structure should relate strongly to the population type, and by inference to the mass of the progenitor star, and less strongly on whether the central star is a member of a close binary system.

The spectroscopic follow-up of our LMC targets with NTT@ESO has also been started, with the aim of obtaining a homogeneous database for LMC PN abundances.

We also observed in more depth the central stars of the faintest LMC PN nuclei with WFPC2 photometry (20 HST orbits), to correlate PN shapes and central star evolution in a distance-bias free environment.

Our study has been extended to SMC PNe (55 HST orbits) in order to determine the late evolutionary paths of the most common stars in a galaxy that, in its chemical content, mimics a young galaxy. We find that the morphological distribution of SMC PNe is different from that of the Galaxy or the LMC, further indicating that morphology depends on galaxian metallicity.

In Cycle 10, two other MC programs with STIS/HST have been approved, to complete the LMC survey (224 orbits, PI: Shaw) and to

measure carbon abundances (28 prime orbits, PI: Stanghellini). The UV spectra of the LMC PNe have been acquired for the most part, and the monochromatic images show very good signatures of the carbon and neon lines, strongest in the UV for PNe.

In the future, our LMC and SMC PN slitless spectra 'images' will form a database of extra-galactic PNe that will far exceed in number the Galactic PNe observed with HST, providing a homogeneous sample for testing the evolutionary implications of metallicity variations in stellar evolution. We have produced a public web page to collect all our results, as a part of the STScI MAST archive: `http://archive.stsci.edu/hst/mcpn/`.

1.6.2 Morphology of Galactic Planetary Nebulae

After the completion of the 'IAC Morphological Catalog of Northern Galactic PNe' (Manchado et al. 1996), a systematic study on the physical characteristics of PNe, their central stars, and their Populations across morphological types has been started. The IAC sample is the only complete and homogeneous PN survey of morphological character, thus it provides the unique opportunity of determining whether the distribution of morphological types that we see at different Galactic locations, or associated with different nebular chemistry, is due to selection effects, distance indetermination, dust absorption, or other systematical biases.

The main findings (Stanghellini et al. 2002) from this investigation, performed in collaboration with Villaver, Guerrero and Manchado (IAC), can be summarized as follows:

60% of Galactic PNe are elliptical, 26 % are round, and 14 % are bipolar or quadrupolar. The statistical distance scale is accurate for this study, and we found that the spatial distribution of PNe varies depending on the morphological types: in fact, bipolar PNe are found closer to the Galactic Plane than either elliptical or round PNe. This segregation, noted before as a marginal effect, has been confirmed by us, for the first time, on a complete, homogeneous, and statistically significant PN sample. We also concluded that the PN sample is really complete up to a distance of about 7 kpc.

The distribution of PN nuclei on the logL-logT plane has been analyzed, and the results of Stanghellini et al. (1993) have been confirmed, i.e., that nuclei of bipolar PNe are, on average, more massive than nuclei of elliptical and round PNe. We will also attempt to relate

the spectral type of the central stars of PNe with the morphology of the hosts.

1.7 Pulsars

Involved people at OAB: D'Amico, Ferraro, Possenti, Sabbi

Four milestones of pulsar astronomy were established in year 2001 by the Bologna Pulsar Group, and these are: a) The discovery of the most massive companion to a radio pulsar; b) The discovery of a substantial sample of new young and energetic radio pulsars, possible counterparts of the unidentified gamma ray sources; c) The first detection of gas in a globular cluster; d) The discovery of a probable new-born millisecond pulsar.

(a) The discovery of the most massive companion to a pulsar

We have found a radio pulsar with a companion at least 11 times the mass of the Sun – the most massive pulsar companion known. The identity of the companion is uncertain: it may be a massive late-type (red) star, a massive but compact blue star, or possibly a black hole. If it is a black hole then this will be the first pulsar – black hole binary system found, and a superb natural laboratory for testing general relativity.

This binary pulsar, PSR J1740-3052, was detected during the Parkes multibeam pulsar survey, a large-scale survey for pulsars currently being carried out using the 13-beam 1400-MHz receiver on the Parkes 64-m (210-ft) radio telescope operated by the Australia Telescope National Facility.

Timing observations made with the 76-m Lovell Telescope at the Jodrell Bank Observatory, U.K., and at Parkes, show that PSR J1740-3052 is a 570 ms pulsar in a 231-day orbit. The orbit characteristics indicate that the pulsar is waltzing through space with a heavyweight companion, which is at least 11 times the mass of the Sun.

(b) The discovery of new young and energetic pulsars

Gamma-ray observations were pioneered in the 1970s by the SAS-2 and COS-B satellites, launched by NASA and ESA respectively. But three decades later many gamma-ray sources still defy identification. To date, less than half of the gamma-ray sources observed with the EGRET instrument on the Compton Gamma Ray Observatory satellite have been identified. The main difficulty in finding counterparts

to gamma-ray sources is that gamma rays are very hard to localize, and so the uncertainties in the source positions can be as much as a degree on the sky.

Young pulsars have long been favoured as potential counterparts. The two most powerful gamma-ray sources in the sky are the Crab and Vela pulsars. The third-strongest source, Geminga, is a pulsar, but has been detected only once at radio wavelengths.

We have now found, as a result of the Multibeam Pulsar Survey carried out at Parkes, about 30 young and energetic pulsars which may be the counterparts of otherwise unidentified Galactic gamma-ray sources.

(c) The first detection of gas in a globular cluster

Using the 64-m Parkes radio telescope in Australia, we have discovered more than 20 millisecond pulsars in the GC 47 Tuc. We have then made very precise observations of the minute changes in the observed rotation rates due to the Doppler shift caused by the gravitational pull of the cluster. This has enabled us to determine their positions within the cluster. A further measurement, made for each pulsar, measures the amount of material and gas in the line of sight to us. We have found that pulsars on the far side of the cluster have more gas in front of them than those on the near side, thus proving the presence of gas within the cluster.

(d) The discovery of a probable newborn millisecond pulsar

Millisecond pulsars (MSP) are old, slow pulsars that have been *recycled*. The pulsar's gravity sucks off gas from a larger companion star. As the gas hits the pulsar surface, it transfers angular momentum to it, making it spin faster. The result is a turbo-charged pulsar spinning at hundreds of times a second. Meanwhile, the enfeebled companion dwindles into a white dwarf.

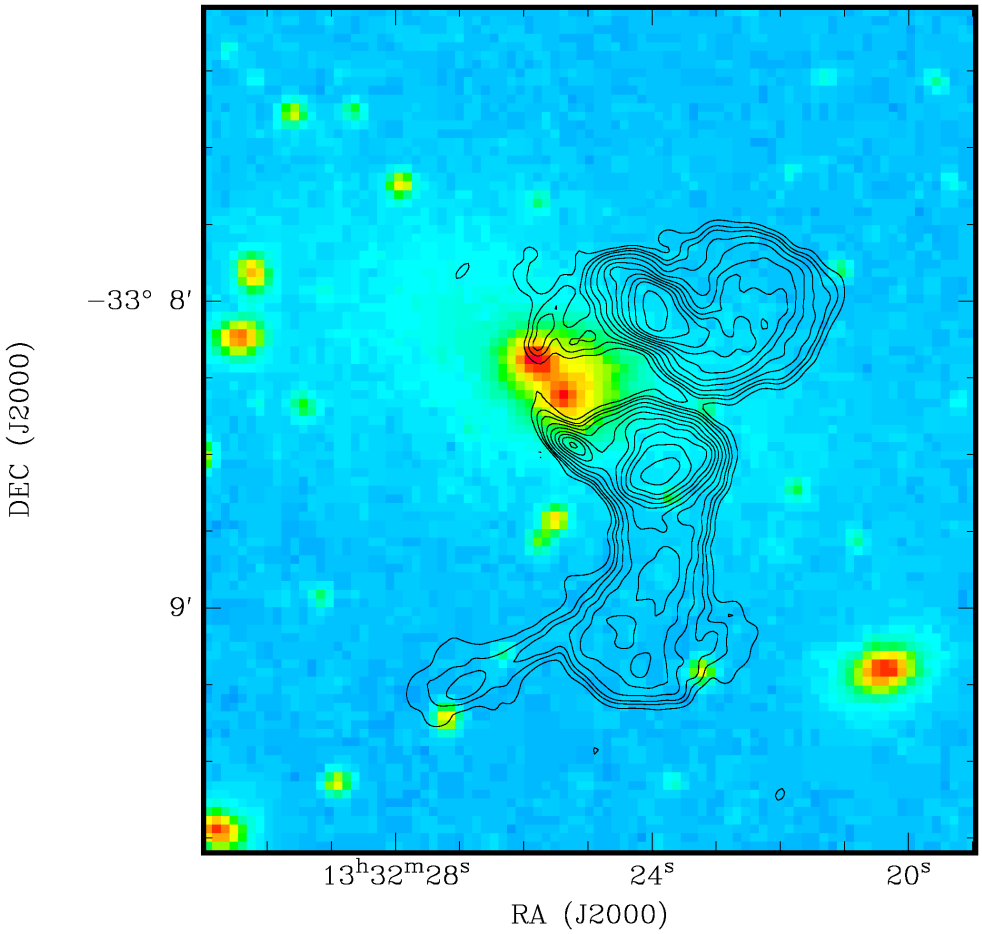
We have started a long-term programme which takes advantage of the current generation of astronomical instruments (from ground and from space) in a coordinated effort to fully understand the formation mechanism and evolution of MSP's in GCs. In particular, our search for optical counterparts to MSP companions in binary systems in GCs has been very fruitful. Two optical counterpart candidates to MSP companions have been identified in the core of 47 Tuc (Ferraro et al. 2001) using deep HST observations in the UV.

However, the most exciting result has been obtained in NGC 6397: during a systematic search of the galactic globular cluster system for

millisecond pulsars (carried out with the Parkes radiotelescope) we have found an eclipsing binary millisecond pulsar (PSR J1740−5340, D'Amico et al. 2001) whose gravity has deformed its companion into a red teardrop. The optical identification (Ferraro et al. 2001) of the companion revealed a bright red star (a tidally deformed Main Sequence star) instead of a white dwarf, and the peculiar modulation of the light curves showed that it had filled and overflowed its 'Roche lobe'. This discovery has had a large "echo" on international science journals (see Public Outreach publications).

This is the first known binary system in which the *overflow stage* is not ended yet and could represent the first detection of a new-born MSP i.e., we are seeing the system in a fleeting phase of its life - the point at which a new millisecond pulsar has just been fully spun up by its companion star. Otherwise, it's also possible that the pulsar has picked up the red star after parting from its original partner.

A coordinated spectroscopic study of this object is currently in progress to determine its origin and true nature. In particular, phase resolved spectroscopy at low (with EMMI@NTT), and high resolution (with UVES@UT2), and high precision multiband photometry (with SUSI@NTT) is going to be secured at ESO Telescopes in the next months. This will allow us to determine the detailed light curve shape, the radial velocity curve, the accurate abundance pattern, and to map the emission of the donor star as a function of the orbital phase. The complete data-set will finally allow a complete characterization of the system and will shed light on the formation mechanism and the evolution of MSP binary systems in Globular Clusters.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VLA radio isocontours (at 20 cm wavelength) of the radio galaxy J1332-3308 in the cluster A3560, superimposed to the optical image from the Digital Sky Survey (Bardelli et al. 2002).

People involved at OAB:

- *Scientific staff:* S. Bardelli, A. Cappi, P. Ciliegi, L. Ciotti, A. Comastri, A. D'Ercole, H. de Ruiter, P. Londrillo, M. Mignoli, L. Origlia, L. Pozzetti, R. Sancisi, G. Stirpe, G. Zamorani, V. Zitelli, E. Zucca;

- *Fellows:* F. Fraternali, B. Lanzoni, F. Pozzi.

Observational extragalactic astronomy has traditionally been one of the main themes of research at the Bologna Observatory. It includes a wide range of subjects, from the structure and evolution of "normal" galaxies, to the physical properties of active galactic nuclei (AGNs) to observational cosmology.
The extragalactic research at the Bologna Observatory is characterized by the lack of "wavelength chauvinism": while optical astronomy is and will remain important at the Observatory, some of the scientific staff specialize in X–ray observations of AGNs, and others find their main interest in radio studies of galaxies and quasars.
Much of this research is based on an intensive use of the most advanced instruments available today: the X–ray satellites Beppo-SAX, Chandra and XMM-Newton, the ESO optical telescopes (including VLT), the infrared satellite ISO, the Westerbork, VLA and ATCA radiotelescopes.

2.1 Structure and evolution of galaxies

The structure of galaxies is studied either from a theoretical point of view (including numerical modeling) or by radio observations of neutral hydrogen.

2.1.1 Theoretical studies and numerical simulations

People involved at OAB: Cappi, Ciotti, D'Ercole, Lanzoni, Londrillo, Zamorani.

The main results in this field are summarized as follows:
• By combining the $M_{bh} - \sigma$ relation with the Fundamental Plane of elliptical galaxies, it was examined the possibility that the dissipationless merging is important in the formation and evolution of elliptical

galaxies. One of the main results of this work is that a major role of dissipation in galaxy formation is strongly required.

• The question of whether a systematic non–homology could be partly responsible for the correlations that define the Fundamental Plane was reexamined. It is found that elliptical galaxies should not be considered homologous dynamical systems and that neither the strict homology nor the constant stellar mass–to–light solution are a satisfactory explanation of the observed Fundamental Plane.

• In the context of the physical interpretation of the Fundamental Plane of elliptical galaxies, the relations between the Fundamental Plane thinness and tilt, and the amount of radial orbital anisotropy, has been studied by using N-body simulations of galaxy models characterized by observationally motivated density profiles, and also allowing for the presence of massive dark matter halos. The main results of this work are that galaxy models that are radially anisotropic enough to be found outside the observed Fundamental Plane (with their isotropic parent models lying on the Fundamental Plane) are unstable, and their end–products fall back on the Fundamental Plane itself. In addition, it was also shown that a systematic increase of radial orbit anisotropy with galaxy luminosity cannot explain by itself the whole tilt of the Fundamental Plane, becoming the galaxy models unstable at moderately high luminosities: at variance with the previous case their end–products are found well outside the Fundamental Plane itself.

• From the theoretical point of view it has been studied how the presence of *abundance gradients* in the intracluster medium affect commonly adopted estimates of the average abundance, assuming various plausible ICM density and temperature profiles. It has been found that, by adopting the observed abundance gradients, the true average mass weighted abundance is less than (although not largely deviating from) the commonly used emission weighted abundance.

• An evolutive scenario which links the X-ray evolution of elliptical galaxies with the QSO evolution and activity has been developed. In this scenario the solution of the puzzling question of the lack of strong AGN activity in the large majority of elliptical galaxies containing a massive black hole at their center (activity naturally predicted in the standard cooling flow scenario) is due to an accretion mechanism modulated by radiation feedback. The feedback is due to Compton scattering of the radiation emitted by the accreting material on the electrons of the galactic hot gaseous halo. This scenario has been ex-

plored in great detail by using a specific numerical hydrocode which takes into account several aspects of radiative transfer. Follwing this work, a robust method to derive the duty cycle of QSO activity based on the empirical QSO luminosity function and on the present-day linear relation between the masses of supermassive black holes and those of their spheroidal host stellar systems has been developed. It application showed that the duty cycle is substantially less than unity, with characteristic values in the range $3 - 6 \times 10^{-3}$, in excellent agreement with the theoretical results presented above.

• Finally, numerical and analytical techniques have been developed to construct axysimmetric dynamical models of elliptical galaxies.

These works are carried on by Ciotti in collaboration with with prof. T.S. van Albada (University of Groningen, The Netherlands), G. Bertin (University of Milano and Scuola Normale Superiore, Pisa) and M. Del Principe (graduate student of SNS-Pisa), S. Pellegrini and C. Nipoti (Dip. Astron. BO), J.P. Ostriker (Cambridge - UK and Princeton - USA University) and Z. Haiman (Princeton University), and Londrillo, Lanzoni, Cappi, Zamorani.

D'Ercole, in collaboration with F. Matteucci, S. Recchi (University of Trieste) and Tosi continued the studies about the effects of SN explosions in starburst galaxies. In particular, 2D simulations have been performed studying the effects of two instantaneous starbursts, separated by a quiescent period, on the dynamical and chemical evolution of Blue Compact Dwarf galaxies. The simulations followed the evolution of a first weak burst of star formation followed by a second more intense one occurring after several hundred million years. The evolution of several chemical abundances and the contribution of both SNII and SNI have been considered. A comparison with IZw18 shows that this starburst galaxy must have experienced two bursts of star formation, one occurred about 300 Myr ago and a recent one with an age between 4-7 Myr.

In the same vein, D'Ercole extended the hydrocode to 3D in order to study problems where the axis-simmetry does not hold. In particular, it is now under study the effect of the ICM ram-pressure on the galactic winds of starburst galaxies.

2.1.2 Neutral hydrogen studies

People involved at OAB: Sancisi, Fraternali.

I. HI halos of spiral galaxies. High velocity gas.

Sancisi, Oosterloo (NFRA) and Fraternali have completed their study of the vertical distribution and kinematics of neutral hydrogen in the nearby spiral galaxy NGC 2403. Such a study has revealed gas with anomalous kinematics ("anomalous gas") located above the plane of the galaxy and rotating $\sim 20 - 50$ km s^{-1} more slowly than the gas in the disk. This gas has a total mass of about 3×10^8 $M_\odot$ ($\sim$ 1/10 of the total HI mass) and shows a large-scale radial inflow ($10 - 20$ km s^{-1}) towards the centre of the galaxy.

Long-slit spectra of NGC 2403 with the WHT (La Palma) were also obtained. The slits ($3.7'$ long) were placed along the major and minor axis of the galaxy. Wings of emission at lower rotation velocities (anomalous ionised gas) similar to those observed in HI have been detected. Also this ionised anomalous gas is rotating more slowly than the regular disk and shows a weak indication of large scale inflow. Local powerful outflows of ionised gas were also found with velocities reaching up to 200 km s^{-1}.

Chandra observations (36 ks) of NGC 2403, obtained in April 2001, show a diffuse soft X–ray emission (0.4−1 keV) from the disk of the galaxy. Such emission (with a total luminosity of $\sim 2 \times 10^{38}$ erg s^{-1} and a gas temperature of $2-8 \times 10^6$ K) is well separated from the numerous bright point sources and is probably produced by hot gas in the disk of NGC 2403.

All the above results seem to point at a galactic fountain type of phenomenon which may explain the presence and kinematics of the anomalous gas in NGC 2403.

Sancisi and Oosterloo have continued their study of high velocity HI with the Westerbork Synthesis Radiotelescope in a number of nearby spiral galaxies. One of these, NGC 4559, shows a strongly kinematically lopsided disk and the presence of anomalous HI as NGC 2403.

Sancisi, Oosterloo, T. van der Hulst and Boomsma (Kapteyn) have started a project to study the vertical motions of the gas in the nearly face-on spiral galaxy NGC 6946. Very deep (16x12 hours integration) HI observations with the upgraded WSRT are planned. These observations are also useful for the investigation of HI holes in the disk and the associated high velocity gas.

II. Luminous and Dark Matter in Galaxies.

Sancisi and Swaters (DTM, Washington DC) have continued their study of the rotation curves and of the light distribution in the central regions of spiral galaxies. The shapes of the HI and optical rotation curves have been compared with the distribution of luminous matter as inferred from photometric profiles.

Sancisi, T. S. van Albada, T. van der Hulst and E. Noordermeer have started a study of the mass distribution in bright compact Sa and Sb galaxies. These galaxies are part of the WHISP (Westerbork Survey of HI in Irregular and Spiral galaxies) sample of galaxies. They are expected to have declining rotation curves in their outer parts. This project is the continuation of the study of dark matter in spiral galaxies of different luminosities and morphological types. The radio data are complemented with R-band CCD photometry.

2.2 Active galactic nuclei and star-forming galaxies

2.2.1 Optical studies

People involved at OAB: Stirpe, de Ruiter, Zitelli.

I. Variability of Seyfert galaxies.

Stirpe, in collaboration with A. Robinson and D. Axon (Univ. of Hertfordshire), is completing the analysis of a sample of broad-line AGN observed spectroscopically in Hα and Hβ, covering a wide range of intrinsic luminosity and redshifts (up to $z \sim 2.5$), with the purpose of studying the distribution of properties of the Broad Line Region and the possible causes of the line profile diversity. An automated procedure was developed to deblend the broad Balmer line profiles from continuum, narrow lines, and other blending lines such as those of FeII, and a data-base of several measured and fitted parameters has been created, including mainly the properties of the broad components of Hα and Hβ, but also of the main narrow lines and FeII blends. Several interesting relations are emerging, such as a lack of extremely concave broad line wings at high luminosities, and a decline in the equivalent width of the forbidden lines with increasing luminosity.

A similar deblending procedure is being applied to high-quality optical spectra of a small group of Narrow Line Seyfert 1 galaxies,

with the purpose of studying their characteristics — particularly the relative strengths and equivalent widths of the FeII and [OIII] lines and their relation to the Balmer lines — in relation to the properties of the same sources in the X–ray band.

Within a collaboration led by A. Marconi (Arcetri Obs.), Stirpe is taking part in the monitoring of high-luminosity, high-z QSOs with the ESO VLT, with the purpose of measuring the emission line vs. continuum light curve lag and thus obtain an estimate of the size of the Broad Line Region. These are the highest luminosity AGN monitored in this fashion and will extend these studies to what are probably the most massive known black holes. Photometric and spectroscopic observations in the K band have been made on a monthly timescale throughout 2001 and will continue in 2002. Analysis of the first data is in progress.

Stirpe is coordinating a possible Italian participation in the *Kronos* monitoring satellite, at present under consideration by NASA as a possible MIDEX mission with B.M. Peterson (Ohio State Univ.) as PI. The Italian contribution would involve individuals from several institutes, and consist in the design and construction of the UV/optical spectrograph planned for the satellite. Stirpe has participated in the preparation of the MIDEX proposal, and coordinated an application to ASI for funding of the Italian segment (currently under evaluation).

De Ruiter, in collaboration with Lub (Leiden Observatory) constructed a database containing many hundreds of photometric and spectroscopic measurements for a sample of about 15 type 1 and type 2 Seyferts in the southern hemisphere, based on fourteen years of observations. These data have now been made available for the general astronomical community: the calibrated spectra can be inspected directly on the WEB[1], or downloaded (in FITS format). Animations that show the lightcurves of a spectral region around 5000 Å are now available at the same WEB page. An article describing the data has been submitted to Astronomy and Astrophysics.

II. HST images of B2 radio galaxies.

De Ruiter, in collaboration with A. Capetti (Torino Obs.), P. Parma and R. Fanti (IRA-CNR, Bologna), and R. Morganti (NFRA, Netherlands), is studying HST images (in two colours, V and I) of

[1] *http://boas5.bo.astro.it/∼deruiter/seyf_spectable.html*

about 60 radio galaxies selected from the B2 sample of low luminosity radio galaxies. Brightness profiles were fitted to all galaxies, and these were used to obtain a detailed mapping of the (circum)-nuclear dust. As expected, in many of the galaxies the dust appears in the form of disks. A discussion of several interesting correlations between the dust and the radio source properties is given in a paper that has been submitted to Astronomy and Astrophysics.

III. The environment of AGN.

Zitelli, in collaboration with Focardi and Kelm (Dip. Astr. BO), is continuing the study of the relationship between nuclear activity and environment for active galactic nuclei. Ample evidences have been reported for a complex environment around active galactic nuclei both in the local universe and up to $z \sim 3$. However, while it is well estabished that radio loud quasars, radio galaxies and BLLacs reside in denser than average regions, the role of the environment and of interactions on Seyfert galaxies is to some extent still controversial. One of the reason for this still open debate is due to the fact that the samples used in these analyses are limited in number. To reduce the statistical uncertainty we have adopted a strategy based on the analysis of statistically significant samples of nearby AGN and appropriate control samples selected on the basis of criteria independent of morphology and environmental properties. A sample of about 300 physical compact groups has been extracted applying an automatic code to a 3-D galaxy catalogue. The global properties of active galactic nuclei are analyzed, in particular the Seyfert fraction within compact groups has been determined (Zitelli et al., Granada 2001). From this analysis it clearly emerges that Seyfert 2 inhabit groups significantly more often than Seyfert 1, confirming once more that locally dense environments discriminate against Seyfert 1. The properties of compact groups hosting an AGN member as compared to those that do not are presently investigated.

2.2.2 Near-IR studies

People involved at OAB: Comastri, Origlia.

I. Probing the starburst-AGN connection.

Optical and UV studies have established the existence of a starburst-AGN connection in Seyfert 2 galaxies, a connection which is believed to extend to the epoch of the formation of bulges and ellipticals. Seyfert galaxies are excellent local laboratories in which this connection can be probed in considerable detail. Their relative proximity allows not only for high S/N, but also for 0.1–1 kpc spatial resolution, thus sampling more closely the physics of the central engine and its environment. In analogy with the booming progress in the research on distant star-forming ("Lyman break") galaxies, which is very much based upon knowledge acquired through careful study of nearby starbursts, understanding the role played by starbursts in Seyferts will provide crucial guidelines for the interpretation of the high z universe, while simultaneously advancing our knowledge of these complex and physics-rich systems. Near IR (1-2.5 μm) spectroscopy offers a unique opportunity to tackle this issue more closely, with the advantages that it allows to detect starbursts even in Seyfert 1's and to sample dust embedded starbursts (neither of which can be done at shorter wavelengths), while simultaneously providing reliable stellar population diagnostics. There are a few major key spectral features in this spectral range to investigate both the stellar and the nebular components: many absorption lines due to neutral metals (Fe, Si, Mg, Ca, Al, Na), molecules (CO, OH) and Pβ, Brγ, [FeII] 1.64 μm in emission, from which it is possible to derive line fluxes, broadening (velocity dispersions) and equivalent widths. During two successful observational campaigns at ESO-NTT with SOFI and at TNG with NICS on July and August 2001, we secured medium-resolution IR spectra of more than 20 active galaxies. Following the successful methodology developed by our group in a few pioneering works (Origlia et al., 1993, A&A 280, 536; Oliva et al., 1995, A&A 301, 55; 1999, A&A 350, 9) we started to perform the following physical diagnostics:

• quantify the contribution of both stellar and non-stellar components (usually hot dust) by analyzing the associated dilution of a few representative absorption features;

• estimate the reddening towards the stellar population and line emitting region through the stellar H-K color and the H recombination line ratios;

• assess the metallicity of the stars through the strength of the absorption features;

• measure the dynamical mass and the stellar mass to light ratio, enabling us to put tight constraints on the *age* of the dominant pop-

ulation.
These diagnostics will allow us to check whether a genuine starburst is present in the nuclear region and compare the age of the nuclear stellar populations in Seyfert 1's and 2's, thus providing a strong test of the unified model. More generally, this will allow us to explore the use of the age of the stars as a clock for nuclear activity and thereby assess the occurrence of evolution within and between activity classes.

This work is carried on in collaboration with E. Oliva (Arcetri Obs. - TNG); R. Maiolino (Arcetri Obs.); R.M. Gonzalez Delgado (IAA, Granada, Spain); R. Cid Fernandez (UFSC, Brazil); T. Storchi-Bergmann (UFRGS, Brazil).

II. Metal enrichment in starburst galaxies.

The near-IR stellar luminosity of starburst galaxies is dominated by massive red supergiants. Such a stellar continuum generally largely dominate over the gas and dust emission (Oliva & Origlia 1998, A&A, 332, 46; Origlia & Oliva 2000, NAR, 44, 257), while in the visual range the nebular emission strongly dilute the stellar absorption lines and dust can heavily obscure the central regions where most of the burst activity is concentrated. Their absorption spectra show many atomic and molecular lines which can be used to infer reliable abundances of key metals (e.g. C, O, Fe and other α-elements). Metals locked in the stellar atmosphere of red supergiants trace the abundances just prior to the last burst of star formation. On the other hand, the hot gas in the nuclear region, probed by X–ray observations, is heated by type II SN explosions and therefore is related to the gas just enriched by the new generation of stars. The X–ray spectra obtained by the new generation of X–ray telescopes (Chandra and XMM-Newton) have a quality high enough to set good constraints on the metallicity of the hot gas in starburst galaxies and possible spatial gradients.
We are undertaking medium resolution IR spectroscopy of a representative sample of starburst galaxies observed with Chandra and/or XMM-Newton, to infer reliable abundances of Fe, C, O, Si, Mg, Ca and Al and to obtain a detailed screening of the most important abundance patterns, namely [C/Fe] and [α/Fe], of the pre-burst medium, locked into the stellar photospheres. By comparing the metallicity of the hot gas with the pre-burst metallicity determined by the IR spectra of red supergiants we will be able to constrain the star formation history and we will have the unique chance of directly witnessing

the enrichment of the interstellar medium by a single burst of star formation.

This work is carried on in collaboration with P. Ranalli (Dip. Astr. BO), R. Maiolino and A. Marconi (Arcetri Obs.).

2.2.3 X–ray studies

People involved at OAB: Comastri.

I. X–ray observations of AGN.

Several observational programs aimed to understand the high energy emission properties of different classes of AGN are carried out at the Observatory using data from Beppo-SAX, Chandra and XMM-Newton satellites.

The capabilities of the Beppo-SAX detectors, and especially the relatively large MECS effective area at high energy (> 5 keV), and the spectral sensitivity of the PDS detector above 10 keV, have been fully exploited to further investigate, with respect to previous observations, the hard X–ray spectral properties of relatively bright AGN.

In this respect the most important result was the discovery of spectral features due to highly ionized matter in the long look observation of the bright Narrow Line Seyfert 1 Galaxy Ark 564. The presence of an ionized iron line at ~ 6.8 keV and a deep iron edge at ~ 9 keV indicates that ionized reflection of the primary continuum is a viable explanation of the observed spectral features. There is no significant evidence of soft X–ray features (as claimed by several authors from the analysis of ASCA data) if the broad band (0.1–10 keV) spectrum is fitted with a thermal black–body like spectrum plus a steep power law component. The X–ray data for Ark 564, and also for a few other objects observed within the Beppo-SAX Core program of Narrow Line Seyfert 1, were complemented by good quality quasi–simultaneous optical and UV spectra. In the case of RE J1034+396, HST and EUVE observations allowed to perform broad band spectral fits with accretion disk models. The results favour a low mass highly accreting black hole.

Thanks to the high energy response of the PDS detector it was possible to uncover, for the first time, extremely high, Compton thick absorption towards the nucleus of the bright Seyfert 2 galaxy NGC 3281. The high energy spectrum of the nearby bright Seyfert 2 galaxy

NGC 526A is well fitted by a flat power law extending up to several tens of keV without any indication of absorption. This result does not fit in a simple AGN unification scheme, highlightening the importance of high energy observations for a better understanding of AGN emission properties. High energy observations with arcsec spatial resolution of extragalactic sources are now possible thanks to the capabilities of the Chandra X–ray telescope. The discovery of extended hard X–ray emission around the bright radio galaxy 3C 219 nicely confirms previous suggestions based on lower resolution ASCA and ROSAT observations. Hard X–ray emission unambiguously associated with radio jets and hot spots has been also discovered in the two quasars 3C 351 and 3C 207.

II. X–ray studies of star-forming galaxies.

The possibility that the 2–10 keV luminosity of starburst galaxies can be a reliable star–formation indicator has been suggested on the basis of a detailed analysis of a well defined sample of nearby star-forming galaxies observed by Beppo-SAX and ASCA. The linear correlation between hard X–ray, far infrared and radio luminosities allowed us to propose a simple formula to derive the star formation rate as a function of the 2–10 keV luminosity. Preliminary results obtained from deep Chandra and radio observations of the Hubble Deep Field North show that such a relation might hold also at high redshift.

This work is carried on in collaboration with P. Ranalli (Dip. Astr. BO).

2.3 Surveys and Observational Cosmology

A large fraction of the staff of the Observatory is involved in surveys of extragalactic objects. Some of these surveys are ongoing long-term projects, but quite a few have started only recently, or will start in the near future, and will require telescope time with new generation optical telescopes like the VLT.

As an aid to observational cosmologists de Ruiter has made available (on the WEB) a collection of cosmological formulas. For a number of models (the standard Friedmann model, flat models with non-zero cosmological constant, and some more exotic ones) distances, volumes and look-back times are given as a function of redshift. In many cases the solutions are given in analytical form. The compendium can be

found on the WEB[2].

2.3.1 VIRMOS deep survey

People involved: Bardelli, Cappi, Origlia, Pozzetti, Zamorani, Zucca.

The Bologna Astronomical Observatory is part of the Consortium for the ESO-VLT Instruments VIRMOS (Visual Infra–Red Multi–Object Spectrographs).

The visual spectrograph VIMOS[3] has been shipped to Chile in December 2001 and has been mounted at VLT-Melipal. It saw its first light successfully on February 26, 2002. Additional commissioning and testing will start at the end of May and VIMOS will soon be offered to the ESO community.

The huge multiplex capabilities of VIMOS will allow to assemble redshifts of large samples of faint galaxies. The Consortium guaranteed time will be used to perform a deep redshift survey of more than 10^5 galaxies selected from both visual (B and I) and infrared (K) defined samples. Given the large number of expected redshift measurements [about 100,000 galaxies from the wide survey (16 sq.deg.) and about 50,000 galaxies from the deep survey (1 sq.deg.)] and the expected redshift coverage (up to z $\gtrsim$ 2, with a median redshift in the interval 0.6 - 0.9), this survey will allow to determine with excellent statistics the evolution with redshift of the luminosity functions in different bands for each galaxy type.
Just a few of the crucial issues which will therefore be possible to address from these data are:
• detailed tests of the predictions of various models of galaxy evolution (e.g. hierarchical versus monolithic models);
• precise estimates, on the basis of a single sample with well understood selection criteria, of the star formation history up to at least z $\sim$ 2;
• studies of the still uncertain nature of the extremely red galaxies (EROS), determining which fraction of them is actually associated to old elliptical galaxies at high redshift and which fraction is associated with dusty starburst galaxies.

As a by-product, since no morphological selection will be applied to the objects to be observed, this survey, with its expected $\sim$ 1000 AGNs

[2] *http://boas5.bo.astro.it/~deruiter/cosmo/*
[3] *http://www.astrsp-mrs.fr/virmos/index.html*

down to I $\sim$ 24.0, will allow the study of the optical luminosity function and evolution of the faint (e.g. Seyfert-like) AGNs in a magnitude range where the selection of the AGN candidates with the standard color and morphological criteria is very difficult and, possibly, largely incomplete.

The survey, which is expected to start at the end of 2002, has already required a lot of scientific preparation. In particular, during the year 2001 we worked on the following topics:

• We collaborated to the production of the photometric multiband ($BVRI + K$) catalogues which will be the starting point of the spectroscopic survey. In particular we applied various tests to these catalogues in order to verify the quality of the data.
We have also explored the effects due to the detection limits, i.e. surface brightness limit and minimum area, and to the photometric measurements in the optical survey CFDF ($I < 24$ and $\mu_I \sim 28$ mag/arcsec^2). Most of the objects have surface brightness well above the nominal limit. We have compared the data with the tracks expected for normal galaxies, and we found that surface brightness selection effects are negligible for $L < 10L^*$ galaxies.

• We are working to the development of tools for the scientific analysis of the survey: in particular, we concentrated on the luminosity function analysis, implementing different estimators and testing their statistical robustness on simulated samples with different completeness.

• We compared the results of different cluster finding methods, applying the various algorithms on simulated samples.

• We are working on the preparation of the tools which will be used in the statistical analysis of the galaxy distribution, in particular on the correlation function and high-order statistics; we are presently testing the best methods to correct for incompleteness and observational biases, and the tools for data reduction.

• Moreover we are studying how to discriminate between cosmological models from redshift surveys; we have studied the Alcock-Paczynski geometrical test and the statistics of gravitational lensing, with a focus on "quintessence" and also more exotic models.

2.3.2 VIRMOS RADIO survey

People involved: Ciliegi, de Ruiter, Zamorani.

The radio survey has been obtained with the VLA at 1.415 GHz in one of the VIRMOS region where deep $BVRI$ band photometry has been already obtained with the CFHT to a limiting magnitude (5 σ) of about 25.5 and, for a fraction of the area, in the U and K bands with the ESO telescopes to a limiting magnitude of $\sim$ 25 and $\sim$ 21.5 respectively. The VIRMOS VLA radio survey has mapped an area of 1 square degree with a uniform noise of $\sim$85 μJy (5 σ). A catalogue of radio sources brighter than the local 5σ threshold has been extracted from the 1 degree radio map. It contains 1054 radio sources, 19 of which are considered as multiple, i.e. fitted with at least two separate components. The sources counts obtained with this radio catalogue are in very good agreement with those obtained with other surveys. In particular, our point at the faintest flux level ($\sim$ 0.1 mJy) is fully consistent (with a more robust statistics thanks to the higher number of sources and the larger area covered) with the points obtained with a very deep radio observation in the Hubble Deep Field (HDF). The preliminary results of the VIRMOS VLA survey have been presented at the meeting *Where's the Matter? Tracing dark and bright matter with the new generation of large scale surveys* (Marseille, June 2001).

Subsequently, using the already available optical data, we performed a preliminary cross-correlation between the radio and optical catalogues considering as possible counterparts all the objects for which the offset between radio and optical positions is smaller than 1.5 arcsec. The final optical identification of all the radio sources will be performed using statistical methods like, for example, the Likelihood Ratio Analysis.

We found 770 optical counterparts in the I band catalogue with an offset smaller than 1.5 arcsec from the radio position. The expected number of spurious identifications within this radius is $\sim$80 leading to an identification percentage of $\sim$65%. This percentage has to be considered as a lower limit, mainly because the automatic procedure adopted so far in cross-correlating radio and optical catalogues can miss the optical counterparts for the more extended and/or complex radio sources. We have verified visually that this is indeed happening in a number of cases. On this basis and taking into account the fact that additional catalogues in other bands will soon be available, we expect that the final percentage of identifications will be at least 80%, which would be one of the highest obtained up to now for a large sub-mJy survey and comparable to that of the HDF radio surveys.

2.3.3 K20 Redshift Survey

People involved at OAB: Mignoli, Pozzetti, Zamorani.

Bologna Observatory participates, with the observatories of Arcetri, ESO and Rome, to an ESO VLT Large Program (PI Cimatti, Arcetri Obs.), which started in 1999. This program (nicknamed K20[4]) aims at deriving the redshift distribution of a sample complete at $K < 20$, i.e. about 500 galaxies selected from a sub-area of the Chandra Deep Field (CDF) and from a field around the quasar 0055-2659 ($z = 3.7$). Seventeen VLT nights have been allocated to this project over a period of two years. The survey has made use of both optical(FORS1/FORS2) and near-IR (ISAAC) spectroscopy. The main scientific goal is to derive the redshift distribution and to compare it with the predictions of different galaxy formation models in order to derive stringent clues on the formation and evolution of the present-day massive galaxies. The main by-products are: the K-band luminosity function and its evolution up to $z \sim 1.5$, the spectral properties of a large number of galaxies, the clustering properties of galaxies, the fraction of AGN in K-selected samples, the improvement and the calibration of the photometric redshift technique. The observations have been completed in 2000 and provided spectra for about 90% of the galaxies with $K < 20$. The spectroscopic data reduction and analyses have been carried out in parallel at Bologna and Arcetri. The photometric sample and completeness analysis will be presented by Cimatti et al. (2002). The scientific analysis of the *first* spectroscopic sample of EROs, selected from our sample, has allowed for the first time to determine the fractions of old and dusty star-forming galaxies in the ERO population (Cimatti et al. 2002) and to derive information on the different spatial clustering of these two classes of EROs (Daddi et al. 2002). Presently we are completing the comparison between the observed redshift distribution of the whole sample of galaxies and the predictions of different models of galaxy formation and evolution. Moreover, in Bologna we are analyzing the spectroscopic sample, both studying the properties of the single object spectra, and constructing averaged template for different spectral classes and/or different redshift bins, with the aim of characterizing a possible spectral evolution. Finally, we have computed the K_s-band luminosity function in three redshift bins up to $z \sim 1.5$.

[4] *http://www.arcetri.astro.it/∼k20/*

These results, already presented at international meetings, will be soon submitted for publication (Pozzetti et al. 2002).

2.3.4 Radio observations of the ESP Survey

People involved at OAB: de Ruiter.

The whole $\sim$ 25 square degree region of the ESO Slice Project was observed at 20 cm with the Australia Telescope Compact Array, using the mosaicing technique (Prandoni, ..., de Ruiter, et al. 2000, paper I: A&AS, 146, 31; paper II: A&AS, 146,41; paper III: A&A, 365, 392; paper IV: 2001, A&A, 369, 787). The resulting radio catalogue (ATESP) contains about 3000 radio sources down to a 20 cm flux limit of $\sim$ 0.4 mJy. The radio data are now being used for various purposes: (a) determining the radio properties of ESP galaxies (e.g. radio luminosity function of various types of galaxies), (b) deep radio source counts and optical identification of ATESP sources, (c) detailed optical studies of smaller selected areas: at present a sample of almost 70 objects, complete down to $I = 19.0$ has been observed at ESO, and spectroscopic data are available for all objects. Spectroscopy of part of the fainter objects has recently been carried out with the VLT. New radio observations (9$\times$12 hours) of the ESP region were done at 5 GHz with the ATCA in August and October 2001; the new data will provide spectral index information for a very large sample of faint radio sources.

2.3.5 Bright galaxies from WENSS

People involved at OAB: de Ruiter, Stirpe.

The Westerbork Northern Sky Survey has mapped the sky (above declination +30°) at 325 MHz (and is complementary to the NVSS survey at 20 cm made by the VLA). The overall catalogue contains about 200,000 radio sources with flux density above 15 mJy. Work is in progress at Bologna Observatory to extract from the WENSS catalogue all radio sources associated with "bright" (i.e. $m_r < 16.5$) galaxies. All the automatic procedures used in the extraction process have now been tested, and a preliminary list of about 4000 WENSS bright galaxies is now available. Several spin-off programmes are now in progress: a number of possible relic radio sources (characterized

by a steep radio spectral index) were selected for further study with the VLA. A series of observations is in progress. Second, a number of distorted (bent) radio sources were selected, since they may be used as tracers of distant clusters. Imaging of the fields around these sources was carried out with the ESO 3.6 m telescope and EFOSC2, in November 2001, in order to study the environments of the sources and establish the presence of distant clusters. The reduction and analysis of the data is in progress.

2.3.6 X–ray Surveys

People involved at OAB: Ciliegi, Comastri, Mignoli.

The Beppo-SAX High Energy Llarge Area Survey (HELLAS) has surveyed for the first time several tens square degrees of the X–ray sky in the very hard 5–10 keV band. A significant fraction of the 147 serendipitous hard X–ray sources has been the subject of detailed X–ray studies and extensive multiwavelength observations. The shape of the hard X–ray counts and the source average spectral properties appear to be consistent with the predictions of synthesis models based on the AGN unification scheme. The relatively large error boxes associated with the Beppo-SAX positions allowed us to build a well defined statistically complete sample of only those HELLAS sources identified with type 1 AGN. A relatively large sample of hard X–ray selected optically identified sources has then been assembled combining the HELLAS data with previous HEAO1 and ASCA observations in the 2–10 keV energy range and used to compute the AGN luminosity function and its evolution in the hard X–ray band. The results confirm the strong evolution of hard X–ray luminosity with redshift. Interesting enough there is some evidence of luminosity dependent density evolution in agreement with the results obtained for soft X–ray selected AGN observed by ROSAT.

The High Energy Large Area survey has been extended making use of 15 XMM-Newton public observations covering an area of about 3 square degrees at relatively shallow hard X–ray fluxes ($F_{2-10keV} > 10^{-14}$ cgs). The approach is complementary to deep pencil beam surveys and samples a different portion of the luminosity–redshift plane. The main purpose of this complementary approach is to study the X–ray source populations at fluxes where a significant fraction of the hard X–ray cosmic background (HXRB) is already resolved ($\approx 50\%$),

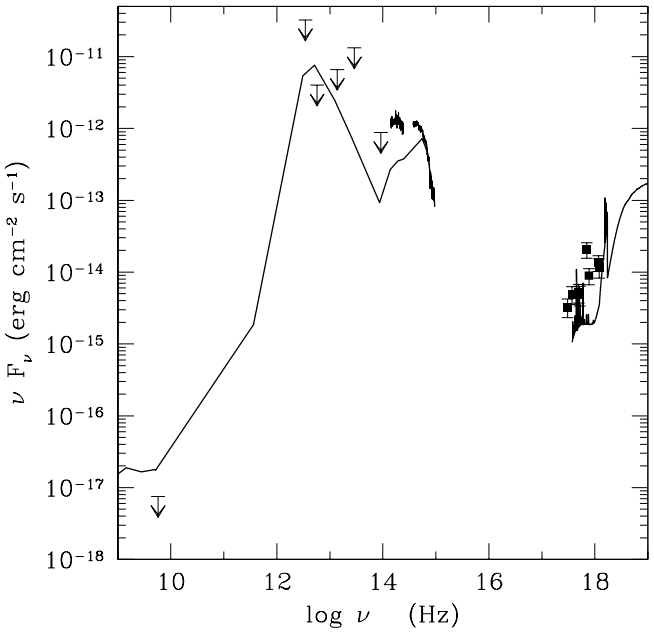


Figure 6: The broad band spectral energy distribution of P3 compared with that of the highly obscured Seyfert 2 galaxy NGC 6240.

but where (a) the area covered is as large as possible, to be able to find sizeable samples of "rare" objects; (b) the X–ray flux is high enough to provide at least rough X–ray spectral information; and (c) the magnitude of the optical counterparts is bright enough to allow, at least in the majority of the cases, relatively high-quality optical spectroscopy, useful to investigate the physics of the sources. Our goal is to evaluate for the first time the luminosity function of hard X–ray selected sources in wide luminosity and redshift ranges. By integrating this luminosity function we will compute the hard X–ray luminosity density per unit volume due to accretion as a function of the redshift.

One third of the HELLAS2XMM fields were selected for follow–up observations in the optical band using the ESO 3.6m and the TNG 3.5m telescopes. At the same time several multiwavelength (radio, sub–mm and near infrared) follow–up programs have been or are being carried out on a fraction of these fields. For one specific field high spatial resolution Chandra X–ray data are also available.

The most surprising finding is the discovery of a sizeable number of relatively bright X–ray sources spectroscopically identified with early–type "normal" galaxies without any obvious signature of nuclear activity in the optical spectra. The large X–ray to optical flux ratio, which exceeds by more than one order of magnitude the average value of early–type galaxies of similar optical luminosity and the hard X–ray spectra, determined from the analysis of X–ray colors, both suggest that (obscured) AGN activity is taking place in their nuclei. Based on a detailed multiwavelength study of what can be considered the prototype of this class of objects (P3, see Figure 6) it has been concluded that an heavily obscured (possibly Compton thick) AGN is the most likely explanation.

Another intriguing result obtained from the optical photometric follow–up program is the presence of a large population of sources with extreme X–ray to optical flux ratio (X/O). While the typical ratio between the 2-10 keV and the R band flux of optically selected quasars is of the order of one, *about one fourth of hard X–ray selected sources has $X/O > 10$, with a few sources with X/O even higher than 100!*. The redshift and luminosity of these source population is today basically unknown. If they are high-z, highly obscured AGN, i.e. quasar 2, they may carry the largest fraction of accretion power from that shell of Universe. Deep infrared and hard X–ray observations are required to investigate the nature of these elusive sources.

This work is carried on in collaboration with M. Brusa (Dip. Astr.

BO).

2.3.7 The ELAIS Survey

People involved at OAB : Ciliegi, Pozzi, Zamorani.

ELAIS is a large European project, involving 19 different institutes, aimed at studying the nature and evolution of the extragalactic sources detected by the Infrared Space Observatory (ISO) in a selected area of the sky (covering 12 sq.deg.). Within this project, we have developed a new data reduction technique for ISOCAM LW data and have applied it to the ELAIS LW3 (15 μm) observations in the southern hemisphere (the fields called S1 and S2, covering respectively $2^\circ \times 2^\circ$ and $21' \times 21'$). The 15 μm data have been reduced and analysed using the *LARI technique*, described in detail by Lari, Pozzi, Gruppioni et al. (2001). With this data reduction method, we have obtained two samples of 462 and 31 sources respectively in S1 and S2, with $S_{15\mu m} \geq 5\sigma$ and in the flux range 0.45 – 150 mJy.

From these data we have derived the 15 μm extragalactic source counts. The large number of extragalactic sources ($\sim$ 350) detected over this area between about 0.5 and 100 mJy guarantee a high statistical significance of the source counts in the previously poorly covered flux density range between IRAS and the Deep ISOCAM Surveys. The bright counts in S1 ($S_{15\mu m} \gtrsim 2$ mJy) are significantly lower than other published ISOCAM counts in the same flux range and are consistent with a flat, Euclidean slope, suggesting the dominance of a non-evolving population. At fainter fluxes ($S_{15\mu m} \lesssim 2$ mJy) our counts do instead show a strong departure from no evolution models, with a very steep super-Euclidean slope down to our flux limit ($\sim$0.5 mJy). Strong luminosity and density evolution of the order of, respectively, $L \propto (1+z)^{3.0}$ and $\rho \propto (1+z)^{3.5}$ is needed at least for the population of star-forming galaxies, in order to fit the counts and the redshift distributions observed at different fluxes. A luminosity break around $10^{10.8} L_\odot$ must be introduced in the local luminosity function of starburst galaxies in order to reproduce our sharp increase of the counts below 2 mJy and the redshift distributions observed for 15 μm sources at different flux levels. The contribution of the strongly evolving starburst population (down to 50μJy) to the 15 μm cosmic background is estimated to be $\sim$2.2 nW m^{-2} sr^{-1}, which corresponds to $\sim$67% of the total mid-infrared background estimate. The results of this work are

reported in the paper Gruppioni, Lari, Pozzi, Zamorani et al., 2002, recently submitted to MNRAS.

In the framework of the follow-up of the ELAIS region, deep radio data down to 0.1 mJy (5σ) have been obtained in both S1 and S2 regions with the Australia Telescope Compact Array (ATCA). While the data in S1 have been analyzed and published in Gruppioni, Ciliegi et al. 1999 (MNRAS, 305, 297), tha radio data in S2 have been analyzed during the year 2001. With a standard reduction procedure, we obtained a complete sample of 75 radio sources down to a 5 σ flux limit of 0.13 mJy. Using optical data obtained with the ESO Wide Field Imager (WFI) in the U, B and I bands and K band data obtained with the SOFI instrument on the NTT ESO Telescope, we found an optical counterpart for 39 of the 73 radio sources ($\sim$52%). A detailed analysis of the photometric properties of the optical counterparts of the radio sources is still in progress.

Moreover, from a cross correlation between the radio and ISO 15 μm catalogues we found 15 radio/ISO associations. Using this small sample of radio/15μm associations we started a project to study the well known correlation between the radio and far infrared fluxes down to infrared fluxes about 2 orders of magnitude lower than those reached by previous surveys. Our preliminary results suggest that the radio-far infrared correlation is confirmed also at very faint flux levels ($\sim$ 0.1 mJy in the radio band and $\sim$ 0.4 mJy at 15 μm). If confirmed with more extended sample (we are now extending our radio/15μm associations using also the radio and infrared data in the S1 region) this result will help understanding the still debated nature of the radio-far infrared correlation.

2.3.8 Deep Extragalactic Surveys in the Marano Field

People involved at OAB: Mignoli, Zamorani.

The *Marano Field* is a southern sky area extensively surveyed in the optical (by means of multicolor imaging, slitless and slit spectroscopy, variability), in the X–rays (with a ROSAT $\sim$ 60 ksec integration) and in the radio band [with the ATCA radio telescope (S_{lim}=0.2 mJy) at 1.4 and 2.4 GHz]. Including the recently performed ISO observations and XMM-Newton deep pointing, it is one of the best studied regions of the sky at all wavelengths.

The existing observations have already provided:

• 70 spectroscopically confirmed AGNs with $B_J \leq 22.5$ (Zitelli, Mignoli, Zamorani, Marano & Boyle 1992, MNRAS, 256, 349).
• A complete sample of 50 X–ray sources (ROSAT data) with $S_X > 3.7 \times 10^{-15}$erg cm^{-2} s^{-1}. Of these, 84% have been optically identified (Zamorani, Mignoli, et al., 1999, A&A, 346, 731). AGNs are by far the dominant class of counterparts of these X–ray sources, representing 71% of the optical identifications obtained. It is interesting to note that, while most of these X–ray selected AGNs would have been selected as AGN candidates also on the basis of their optical colors and morphology, about 10-15% of them would have been missed by a pure optical selection, either because classified as extended or because their colors are not different from stellar colors. Both these incompletenesses tend to become more serious at the faintest sampled magnitudes. These data suggest that only a combined multiwavelength approach can provide a complete census of all AGNs at faint magnitudes.
• A deep radio sample for which $\sim 63\%$ of optical photometric identifications and 50% of spectroscopic identifications, at typically $R_{lim} < 23$, were obtained (Gruppioni, Mignoli, Zamorani 1999, MNRAS, 304, 1999). This work has suggested that the identification content of the sub-mJy radio sources is strongly dependent on the magnitude limit of the spectroscopic follow-up. While at bright magnitude (B<22.5) most of the optical counterparts are star-forming galaxies, at fainter magnitudes most of the optical counterparts appear to be early-type galaxies, probably containing low luminosity AGNs.
• A deep optical multicolor catalogue of an area of about 0.15 sq.deg. in the same sky region, has been obtained through CCD photometry at the ESO NTT telescope in the past years. From this catalog faint quasar candidates with magnitudes up to $B = 23.5$ were selected. A significant fraction of these candidates has been observed spectroscopically with FORS1 at the VLT. The analysis of these data suggests that the efficiency of AGN selection based on the standard criteria (colors + morphology) decreases significantly at B > 23.0. At these magnitude most of the UV selected, point–like objects turn out to be extremely compact narrow emission line galaxies at z $\sim$ 0.6 - 1.2, with the classical broad line AGNs being only about 20% of the total number of candidates. These new data will allow to firmly estimate the surface density of AGNs at $B \sim 23.5$, where very few data exist, and to test at fainter magnitudes the existing models of luminosity function and evolution, which have now been firmly established on

the basis of large samples (2dF survey) limited at $B \sim 21$.
• In 2000 we have obtained new photometric data: using the Wide Field Imager (WFI) operating at the 2.2m ESO telescope, the Marano Field has been observed in five optical bands ($UBVRI$) in a wider region, approximately 30×30 arcmin. The field of view includes a large fraction of the region covered by the XMM-Newton observations and therefore it will allow to identify a large fraction of X–ray sources at a significantly fainter flux level than that reached with the ROSAT data and in a harder X–ray band. This work is carried on in collaboration with G. Lamer (PI), G. Hasinger and other German astronomers.

The mosaic of 8 CCDs that constitutes the WFI layout demands a careful reduction; in the course of the last year specific programs have been used to solve the astrometric problems due to the wide FOV and to pile-up the various images obtained, following a seven-step dithering, in every filter. The data reduction and analysis is now completed: the final images have a extremely good quality (PSF with $FWHM < 1$ arcsec on the *whole* field for the B, V, R filters) and the magnitude limits are fairly deep ($U \sim 23.7$, $B \sim 25$, $V \sim 24.5$, $R \sim 24$). The creation of a multi-color database and the cross-correlation with the existing (NTT, radio, ISO, ROSAT and XMM-Newton) catalogues are now in progress.

2.3.9 Extremely red objects

People involved at OAB: Comastri, Pozzetti.

We have analysed deep observations in the J band, obtained at TNG with NICS, of a complete sample of 57 extremely red galaxies (EROs) selected in the field of Thompson, Aftreth and Soifer (2000) with $K < 20$ and $R - K > 5.3$. Using the Pozzetti and Mannucci (2000) prescriptions, based on the $R-K$ and $J-K$ colours, to separate the two dominant populations, old ellipticals and dusty starbursts, we have found that both populations are present in the current sample and have similar abundances. Galactic stars comprise about 9% of the objects. The starburst galaxies of the present sample are found to give a contribution to the cosmic star formation density similar to the Lyman-break galaxies (Mannucci et al. 2001).

X–ray observations of the largest sample of Extremely Red Objects available to date (∼450 sources), selected in a contiguous area of ~ 700 arcmin^2, have been carried out with XMM-Newton. Five of the

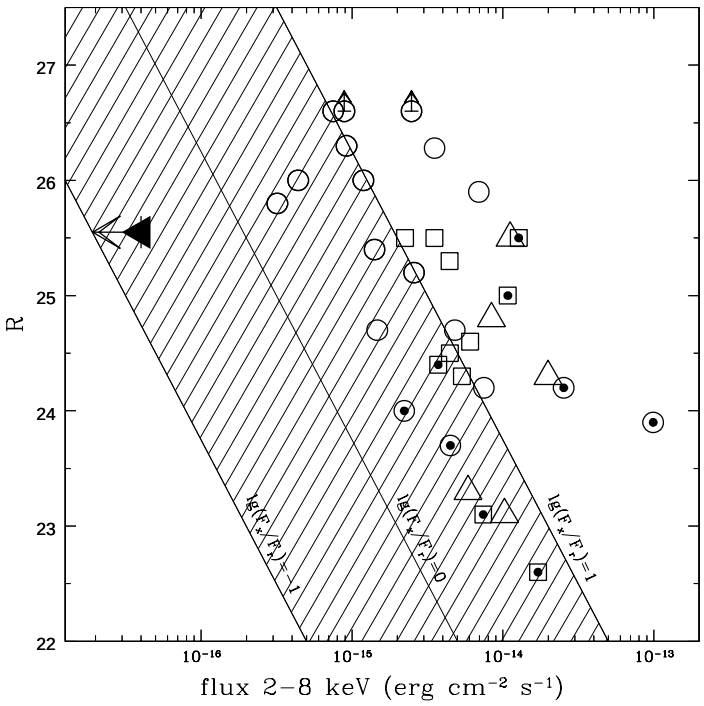


Figure 7: R-band magnitude vs. hard X-ray flux for a sample of EROs serendipitously detected in hard X-ray surveys (see text). The results of stacking analysis of all the EROs in the HDF-N not detected by *Chandra* are plotted at the faintest X-ray flux.

36 hard X–ray selected sources brighter than 7×10^{-15} cgs in the 2–10 keV band are associated with EROs. In order to investigate the nature of hard X-ray selected EROs we have collected all the multiwavelength data available in the literature for objects serendipitously discovered in XMM-*Newton* and *Chandra* observations. In Figure 7 the R band magnitudes are plotted vs. the 2–8 keV flux: all the X–ray detected EROs show rather extreme X–ray–to–optical flux ratios. Circles refer to *Chandra* observations, squares to XMM–*Newton* Lockman Hole observations, and triangles to our sample. Dot–filled symbols represent identified objects (mostly highly obscured, high luminosity Type 2 AGN).

This work is carried on in collaboration with M. Brusa (Dip. Astr. BO).

2.3.10 Extragalactic Background Light

People involved at OAB: Pozzetti.

We have analysed the ultraviolet to near-IR galaxy counts from the deepest imaging surveys, including the northern and southern *Hubble Deep Fields*. The logarithmic slope of the galaxy number-magnitude relation is flatter than 0.4 in all seven $UBVIJHK$ optical bandpasses at faint magnitudes, i.e. the light from resolved galaxies has converged from the UV to the near-IR. We find a lower limit to the surface brightness of the optical EBL comparable to the intensity of the far-IR background from COBE data. Diffuse light, lost because of surface brightness selection effects, may add substantially to the EBL. Most of the galaxy contribution to the resolved extragalactic background light (EBL) comes from relatively bright (50% at $V < 21$ and 90% at $V < 25.5$), at relatively low-redshift ($z < 1$) objects We have moreover estimated the contribution to the optical EBL from two populations of high redshift sources, the Lyman-break galaxies (LBGs) and the extremely red objects (EROs), and derived the predictions for EBL using different star formation histories (Pozzetti & Madau 2001).

2.4 Galaxy clusters and large-scale structure

2.4.1 The Shapley Concentration

People involved at OAB: Bardelli, Zucca.

A long term project in which the extragalactic group is involved is the multiwavelength study of the Shapley Concentration, the richest supercluster in the nearby Universe. This study is devoted to investigate the effect of the environment and of the merging phenomena on the physics of clusters and on their galaxy population. In particular, the central part of superclusters are ideal laboratories where to study dynamical processes, given the high peculiar velocities induced by the density excess.
The main results of this work in the year 2001 were the following:
• In order to explore the effect of cluster mergings on the spectral properties of the galaxy population, a Principal Component Analysis technique (see Figure 8) was applied to a sample of about 2000 spectra (Baldi, Bardelli & Zucca 2001, MNRAS 324, 509). Analyzing

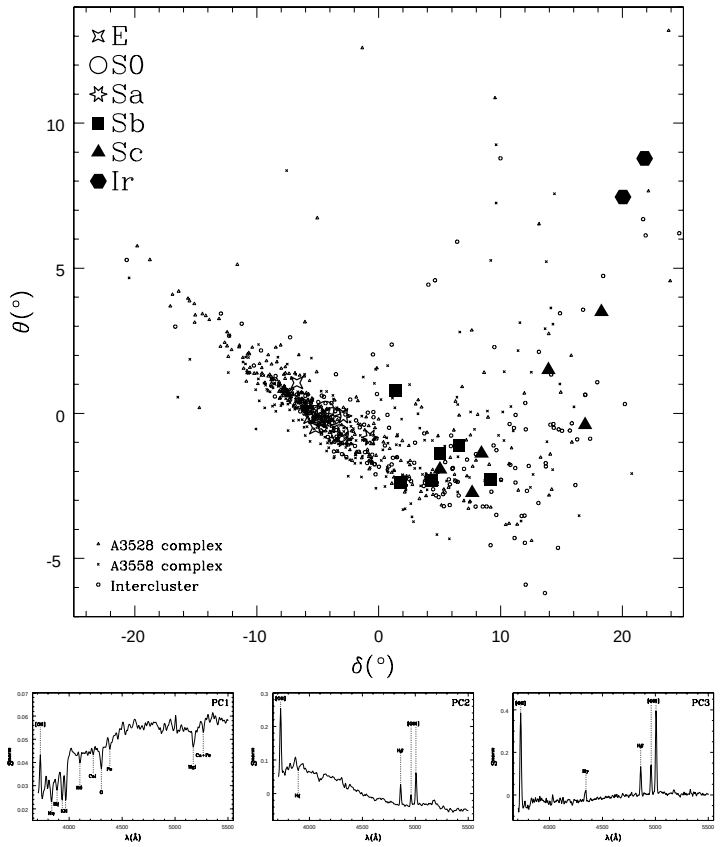


Figure 8: Applying the Principal Component Analysis to a sample of 2000 spectra we found that the sample is represented by a linear combination of three fundamental spectral components (labelled as PC1, PC2 and PC3). Considering the diagram "lines strength" (θ) versus the ratio of the blue over the red part of the continuum (δ), all galaxies follow a sequence reminiscent of the stellar Main Sequence in the H-R diagram.

the spectral type distribution as a function of the local density, previously determined (Bardelli, Zucca & Baldi 2001, MNRAS 320, 387), it has been concluded that the merging phenomenon was not able to substantially modify the morphology-density relation. Moreover these results are consistent with the literature claims that the star formation rate in cluster is lowered with respect to the field.

• We completed the wide radio survey performed on the three structures formed by interacting clusters (the A3558 complex, the A3528 complex and the A3571 complex) which dominate the core of the Shapley Concentration. We identified the optical counterparts of the radio sources and we derived the number counts and the bivariate radio-optical luminosity function for each complex (Venturi, Bardelli et al. 2001, MNRAS 324, 1131; Venturi, Bardelli et al. 2002, A&A 385, 39). This work is carried on in collaboration with T. Venturi, I. Prandoni (IRA-CNR, Bologna), R. Morganti (NFRA, Dwingeloo) and R.W. Hunstead (Sydney Univ.).

• In order to investigate the link between radio and X–ray properties in merging clusters, ROSAT and Beppo-SAX maps of clusters in the Shapley Concentration were analyzed and the physical parameters (temperature, gas distribution and metallicity) of the intercluster medium were derived. In particular, using two Beppo-SAX pointed observations, it has been studied the region in the A3558 complex where a shock is expected, finding no evidence of regions with enhanced temperature, indicating that the gas is in the expansion phase and thus reinforcing the hypothesis that the A3558 complex is an old merging (Bardelli, ..., Zucca et al. 2002, A&A 382, 17).
Further observations have been recently obtained with XMM-Newton on the A3528 complex: the data are currently under reduction.
This work is carried on in collaboration with S. Ettori (ESO), S. De-Grandi (Milano Obs.) and S. Molendi (IFC-CNR, Milano).

From all these analyses we found that the three main cluster complexes in the central region of the Shapley Concentration are part of an evolutionary sequence. In particular, the wealth of information available from radio to optical (both photometry and spectroscopy), up to X–ray energies, suggests the following scenario:

• The A3528 cluster complex is at the very beginning of a merger event, where the two merging entities have just started "to feel each other". The gradients in the temperature distribution of the intracluster gas delineate the merging front (Schindler 1996). The radio

luminosity function of elliptical galaxies is in good agreement with that of ellipticals not located in merging clusters, and no sign of starburst emission, possibly induced by merger shocks, is detected (Venturi et al. 2001). We suggested that the pre-merging stage had not yet had time to affect the radio emission properties of the cluster galaxies in the complex.

• The A3558 complex is thought to be an advanced merger, where two clusters of similar mass have already undergone the first core–core encounter. The amazing similarity between the galaxy distribution (Bardelli et al. 1998) and the gas density distribution (Ettori et al. 1997; Kull & Böhringer 1999) provides further evidence of the ongoing process. In the radio band it was found (Venturi et al. 2000) that this complex shows a significant deficit of radio galaxies in comparison with the radio luminosity function of normal clusters, suggesting that the major encounter switched off the nuclear radio emission and temporarily inhibited its formation. No radio excess of starburst origin was detected with these data in the shock region; data from a deeper survey in the same region are being analyzed (Venturi et al., in preparation).

• We suggest that the A3571 complex represents the final stage of a merger event, where A3571 itself is the resulting cluster after virialization of the merger. The distribution of the gas is already relaxed, as well as the galaxy distribution in A3571, while the outer edge of the galaxy distribution is still unrelaxed. The radio properties reflect the different dynamical stage of the central relaxed region of the complex (the cluster A3571) and the active dynamics of the outskirts. The location of the radio galaxies in A3571 suggests that they had time to develop a nuclear source after the active merging ceased.

Further information about this project can be found on the WEB [5].

2.4.2 The distribution of galaxies as a function of luminosity

People involved at OAB: Cappi.

The analysis of the Southern Sky Redshift Survey 2 catalogue (da Costa et al. 1994) has shown the biasing in the distribution of galaxies as a function of their luminosity (a result confirmed by the recent 2dF survey).

[5] *http://boas5.bo.astro.it/∼bardelli/shapley/shapley_new.html*

Now we are investigating the environment of the most luminous galaxies ($M \leq -21$), which show a correlation length comparable to clusters, but appear to reside in "Local Group-like" systems (Cappi et al. 2002, in preparation).

This work is carried on in collaboration with C. Benoist, S. Maurogordato (Obs. de la Côte d'Azure) and L.N.da Costa (ESO).

2.4.3 Optically selected galaxy clusters with z≤ 1

People involved at OAB: Bardelli, Zucca.

A sample of few hundreds of galaxy cluster candidates has been extracted from the wide angle multicolor ESO Imaging Survey (EIS), using a matched filter algorithm in the I band. The estimated redshift range of these candidates has a high redshift tail reaching $z \sim 1.3$. This sample will allow to determine the structural parameters and the galaxy population characteristics of cluster of different richness in a wide range of redshifts (Da Costa, ..., Bardelli, Zucca et al. 2001, proc. of *ESO workshop on Deep Fields*, Cristiani et al. eds., p.187).
We tested the robustness of our method by comparing the results of the algorithm both in the I and V filter, finding that 75% of the clusters are present in both bands (Olsen, ..., Bardelli, Zucca et al. 2001, A&A 380, 460). We also used the available $(V-I)$ colour to search for the red sequence of early type galaxies, observed in rich clusters over a broad range of redshifts. This is done by searching for a simultaneous overdensity in the three-dimensional colour–projected distance space. We found significant overdensities for $\sim 75\%$ of the clusters in our initial sample of candidates. Moreover we found a good agreement between the characteristic colour associated to the detected "red sequence" and that predicted by passive evolution galaxy models for ellipticals at the redshift estimated by the matched filter.
A great effort has been undertaken in order to have a spectroscopic confirmation of a subsample of these EIS clusters. In the year 2001 we focussed on the high redshift candidates, using the FORS1 and FORS2 spectrographs at the VLT, obtaining more than 500 spectra. In particular, we confirmed three clusters at $z = 0.81, 1.14, 1.30$ (Benoist, ..., Bardelli, Zucca et al., 2002, A&A in press). We note that the two systems at $z > 1$ are the most distant clusters identified so far by their optical properties alone. The cluster at $z = 1.30$ coincides remarkably well with the location of a firm X–ray detection ($> 5\sigma$) in a ~ 80 $ksec$

XMM-Newton image (Neumann, ..., Bardelli, Zucca et al. 2001, proc. of New vision of the X–ray Universe with XMM-Newton and Chandra era, in press).
This work is carried on in collaboration with L. da Costa and S. Arnouts (ESO), C. Benoist (Nice Observatory), L. Olsen and H. Jørgensen (Copenhagen Observatory), A. Biviano and M. Ramella (Trieste Obs.), M. Scodeggio (IFC-CNR, Milano).

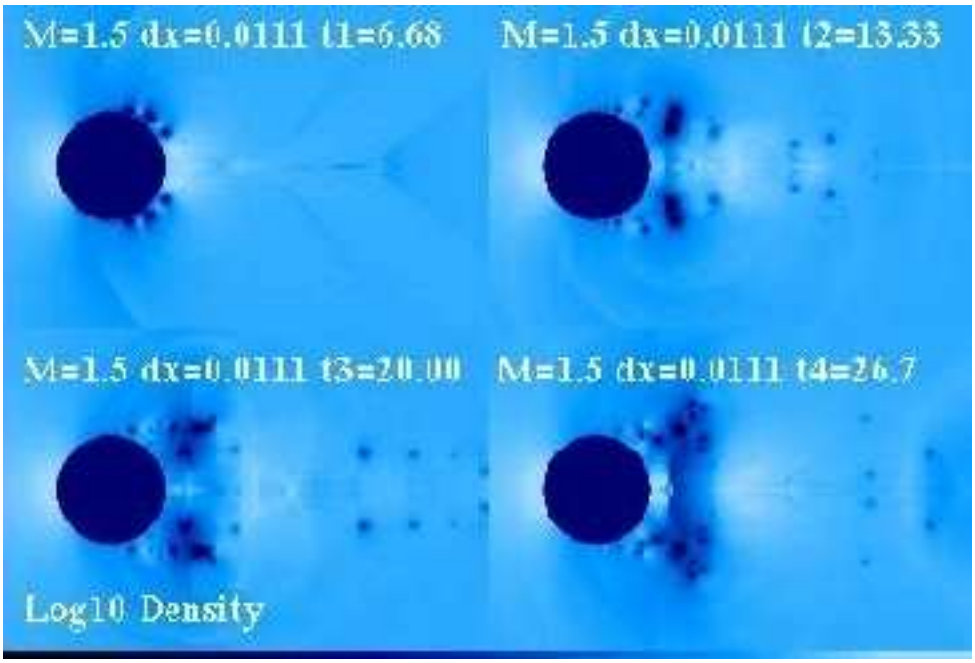
2.4.4 Galaxy clusters and large-scale structure

People involved at OAB: Bardelli, Cappi, Zucca.

Cappi is involved in a project (MUSIC, MUltiwavelength Sample of Interacting Clusters) with researchers at the Observatoire de la Côte d'Azur (Maurogordato, Benoist, Bijaoui, Ferrari, Slezak) and at the CEA/CEN in Saclay (M. Arnaud, J–L. Sauvageot), aiming at a combined optical and X–ray study of galaxy and gas dynamics in a selected sample of galaxy clusters. This project is mainly based on optical observations at the ESO 3.6m and CFHT telescopes, and on X–ray observations with ASCA and ROSAT, and with Chandra and XMM-Newton. A number of results have been obtained for A521, a complex, relatively rich cluster at $z \sim 0.25$, in the middle of two filamentary structures, with on–going merging (Maurogordato et al. 2000, Ferrari et al. 2002, in preparation). New spectroscopic observations have increased the number of known redshifts, giving a detailed map of the substructures and dynamics of this complex system, while more imaging and spectroscopic observations are scheduled to study the star-forming galaxies in the cluster and their distribution. A dynamical study is currently carried out also on another, regular cluster, A1413, for which the Sunyaev–Zeldovich effect has also been detected. Other clusters have been or will be observed and will consititute a database suited for a systematic study of merging clusters.

Bardelli, Cappi and Zucca, in collaboration with a group in Padova (L. Moscardini et al.) and in Milano (S. De Grandi et al.) and with S. Ettori (ESO) have obtained Beppo-SaX observations of two cluster pairs in the Corona Borealis Supercluster; in combination with the available redshifts, it will be possible to analyse the consequences of the merging event on the energetics, internal structure and dynamics of clusters and the interplay between the ambient density, the dark mass, the gas and the galaxy population.

3 Numerical studies and software development



Shock diffraction on a sphere.

People involved at OAB:

- *Scientific staff:* R. Bedogni, P. Londrillo, G. Parmeggiani

3.1 N-body and hydrodynamical codes

People involved at OAB: Bedogni, Londrillo

The research activity in numerical astrophysics has been active in the following fields:

a) N-body code for galaxy merging numerical simulations. A new N-body code, based on the multipole scheme recently proposed by W.Dehnen (2000, ApJL 536, L36), has been inplemented in F90 and parallelized under MPI. The code represents a substantial improvement over existing tree-codes (e.g. the Gadget package), and assures a gain of at least a factor five in cpu time. The main numerical results based on this code will be presented at the INAF-CINECA Conference (Bologna July 4-5 2002).

b) Vlasov equation on a grid for astrophysical plasmas. A four-dimensional (two space + two velocity components) code integrating the electromagnetic Vlasov equation for charged particles on a grid has been developed and tested. The code is based on upwind, high order schemes both in space and velocity coordinates. Results have been presented at the Meudon Conference on *Space Plasma Phenomena* (Meudon, June 18-29 2001).

c) Three-dimensional MHD code for relativistic flows. A previously developed MHD code based on upwind, higher order WENO schemes (P. Londrillo and L. Del Zanna, ApJ 2000) has been extended to the relativistic regime, to cope with high energy astrophysical phenomena in radio jets. Results will be presented at the cited Bologna Conference.

Three dimensional MHD code for turbulence in RFP (Reversed field pinch) in laboratory plasmas. The code is based on spectral algorithms, and takes full account of toroidal geometry, compressibility effects and kinetic transport phenomena. The code is under scrutiny, and has been proposed in the frame of a collaboration activity with the Calabria Physics Department, to study relaxation and anomalous transport in weakly collisional plasmas.

d) The computation of the flow around a rigid object has been extended to the case of a cylinder in order to compare the behaviour of the drag with those of other computations carried out by different authors in numerical hydrodynamics literature.

The results above described have been applied to the investigation of protogalactic and protostellar formation. The effects of a variable drag are included in a one-dimensional code to follow the gravitational collapse of one and more clouds during a process of protogalactic and protostellar formation. In the same context, also the evolution of SN remnants interacting with clouds in the interstellar medium, both for Type I and Type II supernovae, has been computed, focusing in particular on the physical properties (e.g., kinetic energy, drag, mass loss by the cloud) of the turbulent wake behind the cloud.

3.2 StarFinder

People involved at OAB: Parmeggiani

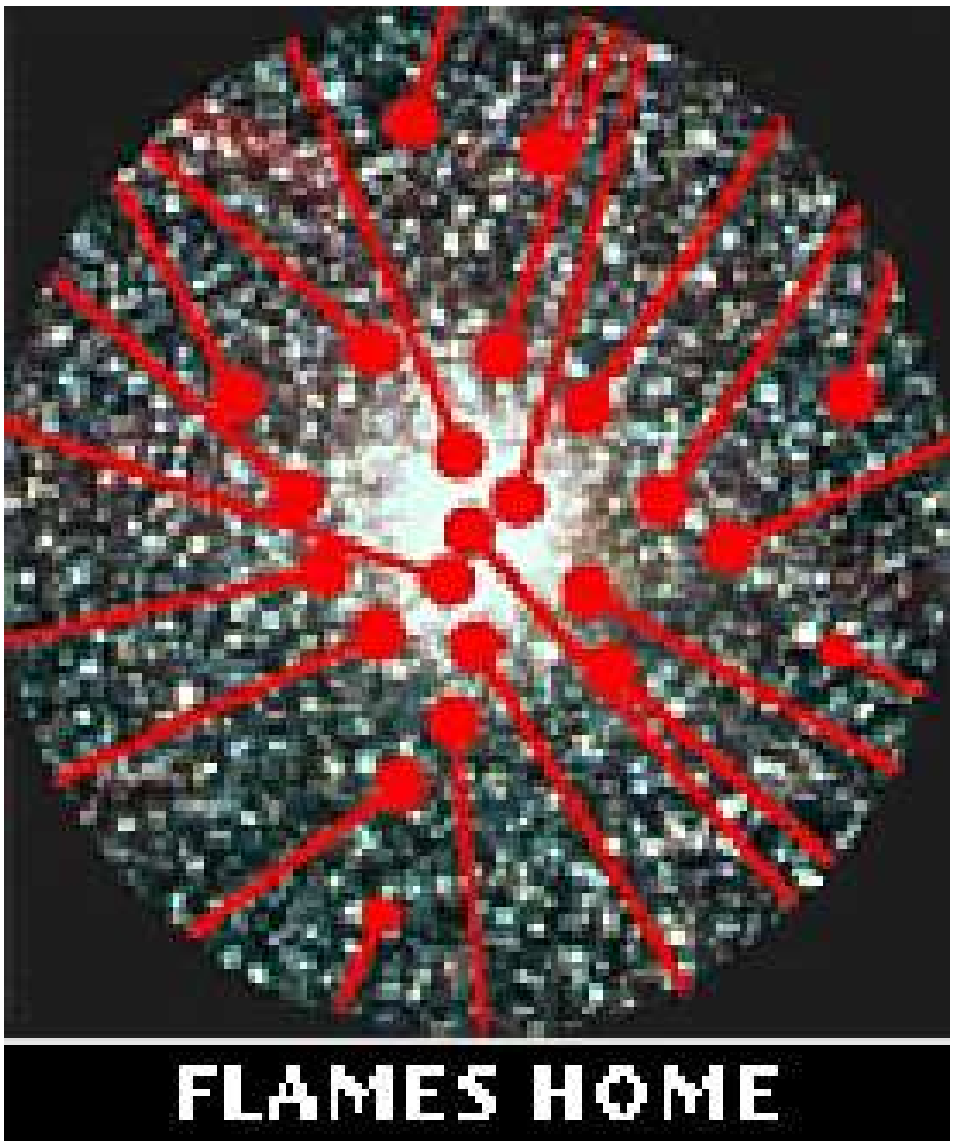
Parmeggiani, in collaboration with E. Diolaiti (Post Doc, University of Padova), improved their original code *StarFinder*.

The StarFinder code has been designed for the photometric and astrometric analysis of crowded stellar fields. It has been applied to high and low resolution images, obtained by different techniques (Adaptive Optics, HST, seeing-limited ground-based observations).

The current version of the code assumes a uniform Point Spread Function (PSF) across the field. Some preliminary tests on wide field seeing-limited observations have been performed, partitioning the image into sub-regions and extracting a PSF for each sub-frame. This approach has proven to be not very satisfactory, showing that a better modelling of the continuous variation of the PSF across the image is certainly required. Other tests have been performed, trying to reproduce the PSF at any field location by degrading the on-axis response with a semi-empirical model, calibrated on several field stars. All the above reported tests are somewhat preliminary and the implementation of a robust though flexible technique to handle a spatially varying PSF is now a major development issue of the code.

StarFinder has been specifically designed for images characterized by complicated and highly structured PSF. Also due to this approach, it is able to detect the stellar sources with high reliability, even in a crowded environment. An interesting development related to this

feature is the classification of stellar and non-stellar sources in a mixed field. Exploiting the image matching methods currently implemented in the code, it might be possible to accomplish this task with high reliability. While a complete object classification is beyond the current plans, this extension of the program should be intended as a way to recognize the point-like sources in a mixed field image, thus allowing a better detection of the extended objects.


FLAMES HOME

Schematic representation of the fiber positions for the VLT FLAMES spectrograph (`www.eso.org/instruments/flames/`*)*

Involved people at OAB:

- *Scientific staff:* N. D'Amico, C. Cacciari, F. Ferraro, L. Greggio, R. Merighi, V. Zitelli
- *Technical staff:* R. Mezzini, C. Ciattaglia, G. Innocenti, G. Bregoli, A. Marchesini, M. Lolli, P. Montegriffo, E. Rossetti.

4.1 TNG

Involved people at OAB: Zitelli, Ciattaglia.

Zitelli (with Ortolani from Padova, Mancini from Napoli, and Porceddu from Cagliari) is a member of the working group "site testing" for the Telescopio Nazionale Galileo (TNG). At present, close to the Galileo site, there are the two towers for the meteo and seeing monitoring that are routinely sending meteo and seeing data. The analysis of such data and additional experiments will allow to obtain a more complete characterization of the TNG site. Particularly important is the analysis of atmospherical dust, coming from Sahara desert, by means of a dedicated dust monitor located at the mirror level of TNG. The aim of this experiment is to compare the behaviour of dust grains of different size and to check the influence of such behaviour on astronomical seeing.

The collaboration of Zitelli and Ciattaglia with Held (Padova Obs.) on the slit drilling machine for the low dispersion spectrograph at the Galileo National Telescope has been completed. This Multi Objects Mode is an extended capability complementary to the real time built-in multislit facility and makes possible to obtain simultaneous spectroscopy of many tens of objects over a useful field of 6×9.5 arcmin^2. The success of this MOS is demonstrated by the large number of requested nights by the astronomical community.

Zitelli is involved in a joint project with Padova, Merate, Catania and Torino observatories to implement a tunable filter (TF) at one of the instruments permanently mounted on the focal plane of TNG. This project has the necessary financial support to complete the feasibility study. The proposed etalon TF allows to obtain sequential narrow-band images spaced, if combined with Dolores, by $6 - 21$ Å, forming the image cube. The other main characteristics of the proposed TF

combined with Dolores are: FOV of 240 arcsec (at f/11), resolving power 300-1000 and spectral range 5800-7500 Å.

4.2 The VLT Project VIRMOS

Involved people at OAB: Bregoli, Lolli, Marchesini, Merighi, Montegriffo.

The OAB is involved in the ESO-VLT Project VIMOS. The VIMOS project has been successfully tested at the end of this year in laboratory and then moved to Paranal. Commissioning of the instrument at the telescope has started in early 2002. Aim of the project is to deliver 2 spectrographs for the ESO-VLT. VIMOS is a visible imaging spectrograph with outstanding multiplex capabilities, allowing to take spectra of more than 800 objects in an area of $\sim$ 220 arcmin^2 (four quadrants of about 7×8 arcmin each). NIRMOS is a near IR imaging spectrograph with a multiplex capability of 180 spectra (10 arcsec slits) over the same area. Together VIMOS and NIRMOS will allow to get spectroscopy from 0.37 to 1.8 μm, with unsurpassed efficiency for large surveys.

The OAB is mainly involved in the development of the imaging and astrometric part of the DRS (Data Reduction Software) and of the RTD (Real Time Display). DRS software must perform on-line (pipeline sequence) and off-line data analysis from raw data to fully reduced images (both direct imaging and spectra), while the RTD must allow quick-look of the data and a minimal on-line data assessment.

4.3 New Pulsar system for the 32mt dish

Involved people at OAB: D'Amico, Innocenti

The new pulsar data acquistion system was fully commissioned in 2001. This system will be used at the italian 32mt dish in Medicina to observe Pulsar radio sources. Long term timing observations of pulsars give information about the interior structure of neutron stars and is useful in the understanding of the evolution of neutron stars. In timing observations, the radio frequency signal needs to be sampled in the time and frequency domain, in order to dedisperse and detect the radio pulses. The radio frequency signal is down converted from the sky frequency of 1.4 or 1.6 GHz into 4 IF bands, each one from

16 to 48 Mhz as required by the front-end filter bank (two adjacent bands for each circular polarization). Each IF band is splitted into 32 1MHz bw channels by the filter bank, square law detected, pass-throw a programmable antialiasing filter, then digitized at 1 bit and by a fast data link built with CERN S-LINK interface; data acquired by a Pentium computer with Linux operating system will be stored on DLT tapes for off-line analysis. Time tag of data acquired is very important, so all operations are synchronized to UTC time reference by GPS receiver and sampling rate clock generator is synch to H-Maser reference.
The parameters of the data acquisition subsystem are:
• 2 x 64 x 1MHz filter bank (left and right polarization) designed at Jodrell Bank Observatory GB
• 128 channel antialiasing filter 2 poles programmable (0.9KHz, 1KHz, 5 Khz, 10Khz)
• 128 channel low frequency integrator (0.5 Hz) for interference monitoring system
• 128 channel 1 bit digitizer
• Synch to H-maser UT clock, programmable sampling rate (10uS-100uS)
• Femb board (digitizer to slink interface, Fpga xilinx based)
• Fast link to Personal computer By E-Slink form Nowoczesna Elektonica (LSC & LDC) & Pci to S-Link by Incaa
• PentiumIII-500MHz 128MB ram, Linux OS Red Hat 6.1
• Data storage on DLT tape unit (up to 20GB on a single tape)
• GPS Motorola Oncore UT+

The system has been calibrated on a number of know pulsars, using the standard timing software for offline analysis, and has shown good performances, although some issues related to the interference clipping need to be solved.

This work is carried on in collaboration with A. Maccaferri (IRA/CNR).

4.4 OmegaCAM project

Involved people at OAB: Greggio

OmegaCAM is a wide field optical CCD camera which will be mounted on the VLT Survey Telescope (VST) on Paranal. The main purpose of VST, a 2.6 m telescope which is being built by the Capodimonte Observatory and will be managed by ESO, is to carry on

long term surveys, and to provide targets for the VLT. OmegaCAM will be equipped with a 16K×16K pixels CCD mosaic, to cover 1 square degree field of view, and is expected to become operative during the year 2003. The camera is built by a consortium of three European institutions and ESO. The institutions are: Universitaets Sternwarte Muenchen (Germany), NOVA-Kapteyn Instituut Groningen (The Netherlands) and Padova Observatory (Italy), each coordinating the activity of other institutes in their home countries, which are associated to the project. Bologna participates to the OmegaCAM project with the contribution of 1.5 man/year provided by Greggio, as responsible of the project documentation.

In the year 2001 the project went through the phase of preparation of the Final Design Review, which took place on September 21, 2001. After taking care of a few recommendations from the ESO board, OmegaCAM has successfully passed FDR, and the manifacturing phase has already started. Five major team meetings have taken place during 2001, to proceed toward the final design of the instrument. (Goettingen in January and December; Padova in March; Munich in May and Naples in July). The choice of the filters has been defined and the first filters have just been ordered at SAGEM (France).

4.5 FLAMES project

Involved people at OAB: Cacciari, Ferraro, Merighi, Rossetti.

The Bologna Observatory is member of the Ital-FLAMES Consortium (including also the Observatories of Trieste, Cagliari and Palermo) that participates to the completion of the FLAMES project. FLAMES is an instrument facility for multi-object spectroscopy developed at ESO. It consists of several components: a Nasmyth corrector, a fiber positioner, a fiber link to the UVES high resolution spectrograph, an intermediate resolution optical spectrograph (GIRAFFE) with its own fibre system, and a coordinating observing software. As part of the Ital-FLAMES Consortium, the OAB provides the Templates for FLAMES in all observing modes. This activity is carried out by the contractor E. Rossetti under the supervision of Ferraro and Merighi, in collaboration with personnel at ESO and the Trieste Observatory, and with the coordination of Cacciari, P.I. of the Ital-FLAMES Consortium. The FLAMES facility is now completed and presently undergo-

ing commissioning tests. It is planned to be offered to the community with the ESO Call for Proposals of September 2002.

4.6 L3CCD project

Involved people at OAB: G.Bregoli.

After the production, from Marconi Applied Technologies, of new intensifier CCD sensors able to detect very low level of light, a collaboration has been established with the Arcetri Observatory to test these sensors and develop their use as imaging photon-counters to be used as wavefront detectors for adaptive optics systems. This activity started in October 2001 and is carried out in collaboration with I. Foppiani and G. Cosentino (Dip. Astron. BO).

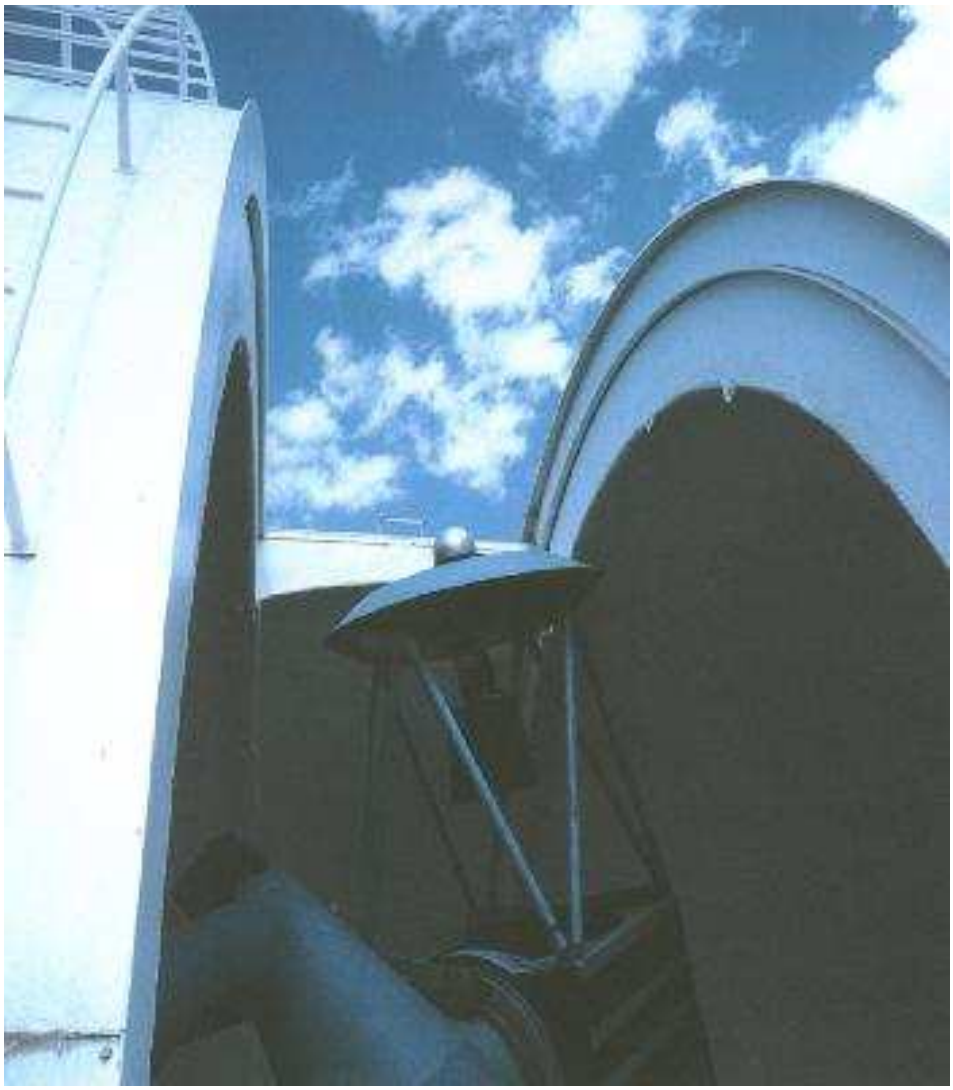
At present the optical laboratory for testing the equipment has been set up.

4.7 Light Pollution

Involved people at OAB: Zitelli.

Zitelli is continuing her activity for the protection of astronomical sites from light pollution. Since 1999 she is involved in the astronomical site protection. After having established a Technical Standard (UNI10919) for the reduction of light pollution, to limit the upward scattered luminous flux emitted by the lighting devices, and having defined the technical requirements of lighting installations to that purpose, she has frequent contacts with public administrations, in particular of Loiano and Bologna, which have to apply this standard.

5 Loiano observing site



The 152 cm telescope at the Loiano observing site

Involved people at OAB:

- *Scientific staff:* R. Merighi, V. Zitelli.
- *Technical staff:* S. Bernabei, A. De Blasi, R. Gualandi, I.Bruni, R. Mezzini, I. Muzi, P. Salomoni, G. Bregoli, C. Ciattaglia, G. Innocenti.

Loiano, observing site of Bologna Observatory, is located at 785 m above sea level and at 37 km from Bologna. In Loiano are located 3 buildings (two hosting the 152 cm and 60 cm telescopes, and one the guest house), and 23 hectares of wood. Zitelli is the person in charge of Loiano observing site.

The 152 cm telescope, dedicated to G.D. Cassini, was built by Reosc and has been operated since 1976. A general description of Cassini telescope is given in Table 1.

The main focal instruments presently available at the telescope are:

1. A spectrograph/focal reducer, BFOSC (Bologna Faint Object Spectrograph and Camera), based on transmitting optics ranging from 330 to 1100 nm. It is equipped with a CCD camera EEV 1340×1300. A Thomson CCD 1024×1024 can be used as backup system.
   Two sets of filters are available: a standard Johnson-Kron-Cousins system and a Gunn system.
2. A "classical", cooled, five colour Photoelectric Photometer .
3. A two channel Photoelectric Photometer (3 colours).

BFOSC has been the most scheduled instrument, with about 80% of the total allocated time.

The 60 cm telescope was built in 1933 by Zeiss of Jena. It was originally equipped with a photographic camera at the f/3 direct focus. Recently it was modified to a f/20 Cassegrain and in the focal plane it can be mounted either a photoelectric photometer or a new CCD Peltier cooled (with a Marconi chip and camera controller from Italian DTA). With these two instruments it is possible to use the time of this telescope for both a scientific use and teaching activities for the graduate students.
From April to September the telescope hosts, since 5 years, also an educational activity in collaboration with Loiano council.

Table 1. Cassini telescope

Mount type	English
Optical configuration	Ritchey-Chretien
Main mirror diameter	152 cm
Focal ratio (main mirror)	f/3
Cassegrain focus	equivalent focal length 1200 cm
	equivalent focal ratio f/8
	scale 16.8 arcsec/mm
	FOV 70 arcmin

5.1 Operations and use of 152 cm

Involved people at OAB: Zitelli, Bernabei, De Blasi, Gualandi, Bruni, Mezzini, Muzi, Salomoni, Bregoli, Ciattaglia, Innocenti.

The 152 cm telescope G.D. Cassini is available for about 350 nights/year, but only about half of this time is really useful for observations, due to weather conditions. The statistics of the last years is given in Table 2. Time is allocated every 6 months, trying to avoid excessive fragmentation of observing time, which would not be efficient with respect to the completion of the accepted observing programs, given the typical weather conditions of the site. The resident staff is composed by 7 technicians.
It is possible to perform a pre-reduction of the observations at the site with a PC in a local network with the PC for the observations. MIDAS and IRAF packages are also available.

Table 2. Cassini Telescope – Nights used per year

nights/year	1995	1996	1997	1998	1999	2000	2001
used (t>50%)	118	106	122	105	98	110	121
used (t<50%)	27	26	19	41	22	38	35
used for test	10	37	32	58	33	15	10
not used (weather)	169	183	180	142	179	189	163
not used (technical)	4	3	1	10	4	1	3
not assigned	37	11	11	10	29	13	33

5.2 Applications to the 152 cm Telescope

1. Bartolini et al. (Univ. BO): *TOO for GRB*

2. **Clementini, G.**, **Tosi, M.**, **Merighi, R.**, **Bragaglia, A.**, **Di Fabrizio, L.** (OAB): *CCD photometry of RR Lyrae "anomalous"*

3. Giovannelli, F. (IAS-CNR) et al.: *Search of binaries Xray emitters at high and low mass*

4. Israel, G.L. (OAR) et al.: *Optical stydy of a sample of new X-ray pulsators*

5. Piccioni, A. (Univ. Bologna) et al.: *Photoelectric observations of binary stars*

6. Vigotti, M. (BOIRA/CNR):: *Observations of a sample of high redshift quasars*

7. Focardi, P. (Univ. Bologna) et al.: *Interaction effect on galaxies*

8. Silvotti, R.: *Whole Earth telescope campaign on PG1336-018*

9. Silvotti, R.: *Secular variation of the pulsation periods on the new discovered sdB pulsator HS2201+2610*

10. Guarnieri, A. at al. (Univ. Bologna): *Spectrophotometric observations of GRB and X Binaries*

11. Tozzi G.P.: *Observations of comet 9P/Tempel1, target of the mission deep Impact*

12. Saracco P.: *Evolutionary properties of irregular galaxies*

13. Negueruela, I. (ASI) et al.: *Distant spiral tracer*

14. Negueruela, I. (ASI) et al.: *Monitoring of massives X-ray binaries*

15. Tajer M. (Brera): *The galaxies in the Brera Multiwavelet Sample*

16. Terranegra, L. et al. (OAN): *A spectroscopic study of IR triplet of CaII in WTTS as stellar activity index*

17. Marconi, M. et al. (OAN): *Monitoring of delta scuti candidates*

18. Polcaro, V.F. (CNR/IAS): *High mass stars in open clusters*

19. Gavazzi, G. (Brera) et al.: *Redshift measurements in A1367*

20. Di Martino, M. (OATO) et al.: *The physical nature of Trojan asteroids: a spectroscopic survey*

21. Cremonese G. (OAPD) et al.: *Light curves of the outer Jupiter satellites*

22. Masetti, N. (ITESRE/CNR): *Optical identifications of the X-ray source 3U1822-00*

23. Smriglio, F. (IAS): *CCD multicolor photometry in the Vilnius System*

24. Bonifacio, P. (OATs) :*Searching for Local Group galaxies in Aquila*

- Applications for undergraduate students of astrophysics:

    1. Righini (OAA): 6 nights
    2. Gavazzi (Brera): 10 nights

- Tests:

    1. Silvotti, R. (OAN): *TTCP photometer*

5.3 Scientific production involving the 152 cm Telescope

1. Gavazzi G. et al., 2001, *The velocity field of UGC6697 revisited* A&A 377, 745

2. Bartolini, C. et al., 2001, *GRB010222 HST/Chandra TOO* GCN 994

3. Bartolini, C. et al., 2001, *GRB010222 BV optical observations* GCN 982

4. Bartolini, C. et al., 2001, *GRB010126 optical observations* GCN 929

5. Bartolini, C. et al., 2001, *GRB010126 optical observations* GCN 924

6. Israel, G.L. et al., 2001, *The identification of the optical-IR counterpart of the 29.5-s transient X-ray pulsar GS1843+009*, A&A 371, 1018

7. Masetti, N. et al., 2001, *X-ray and optical Monitoring of the peculiar Source 4U 1700+24/HD154791*, conference proceedings

8. Marconi, M., et al., 2001, *New observations of the pulsating PMS star V351 Ori*, A&A 372, L21

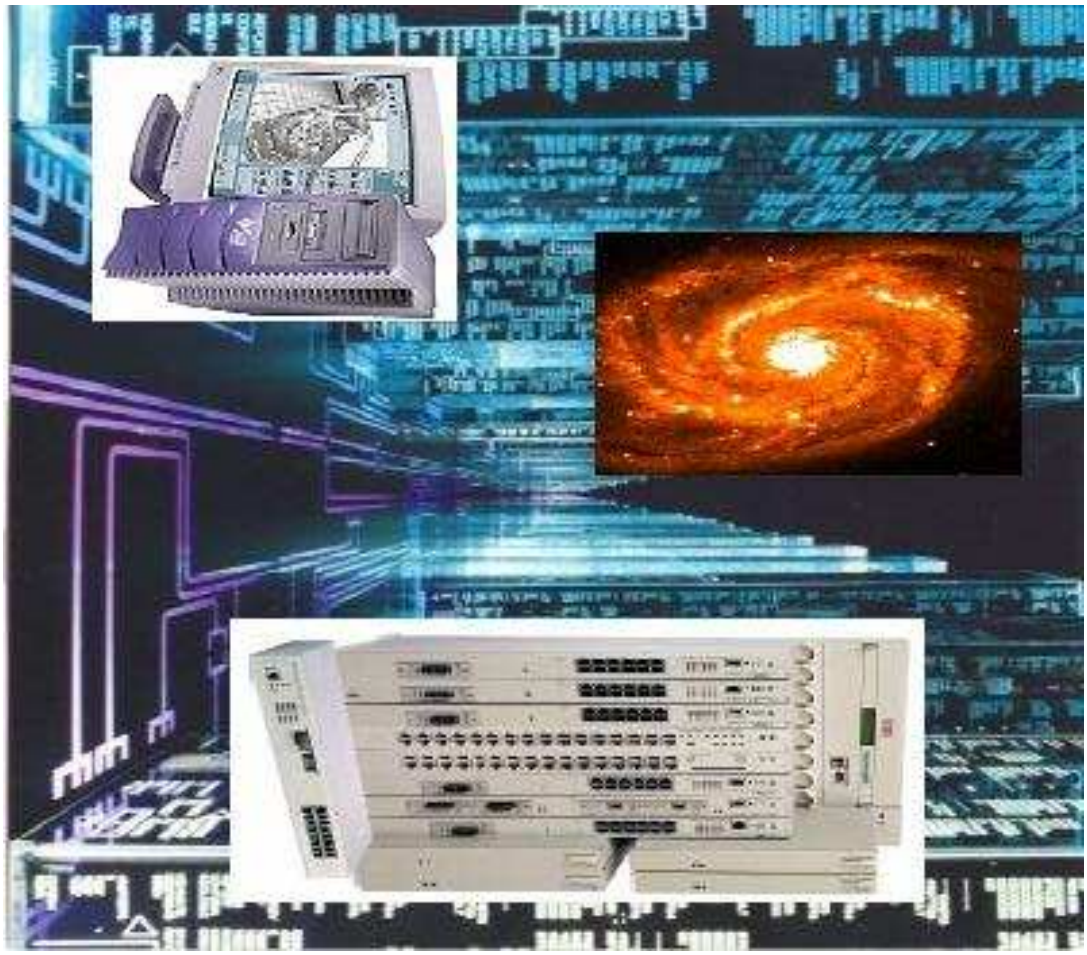
9. Bernabei, S., Polcaro V.F., 2001, *A search for peculiar objects in young open cluster II. New emission line and late spectral type stars in NGC 6871*, A&A 366, 817

10. Masetti, N. et al., 2001, *GRB010222:Afterglow emission from a rapidly decelerating shock*, A&A 374 382

11. Bernabei, S., Polcaro, V.F, 2001, *A search for peculiar objects in young open cluster I. A new Be star, the optical counterpart of IRAS 19564+3224 and a new open cluster in Valpecula*, A&A 371, 123

12. Bernabei, S., 2001, *A search for optical counterparts to X-ray sources in the WGA catalogue*, Vulcano workshop.

6 Computer center and computer network



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Involved people at OAB:

- *Scientific staff:* F. Delpino, R. Merighi;
- *Technical staff:* R. Di Luca, M. Gatti, M. Lolli, G. Madama, P. Montegriffo, R. Policastro.

6.1 Introduction

The principal activity of the computer center during year 2001 has been addressed to the improvement of the computer facilities. In particular, old computers have been replaced with newer ones or have been hardware updated. For what concerns storage space, new disks have been mounted and new network file server added to the system.

6.2 Computer center improvements

Involved people at OAB: Delpino, Di Luca, Gatti, Lolli, Madama, Merighi, Montegriffo, Policastro.

During 2001 the hardware update of the computer center was continued. Old Alpha workstations were replaced with newer ones or with PCs running Linux OS. Several high performance PCs, equipped with AMD Athlon XP 1800+ and 1GBy RAM have been installed, working typically as personal computer facility for large data reduction programs. For this purpose, these machines were also equipped with DAT and CD-RW units, for data backup.

A new Compaq DS20, with 4 Gby of memory and 18+70 GB of disk, has been added to the numerical computing group. A RAIDTEC network file server with 240 GBy in RAID 5 has been installed as a store and backup facility. This unit works as a file server for software distribution and data storage for both system and personal users.

The number of PCs used as Unix-Linux workstations increased during 2001 reaching the number of about 100 units, plus several PCs running Win98. Most of them have been updated with CD-RW and SCSI DAT tapes.

6.3 Improvements in the geographic network

Involved people at OAB: Delpino, Di Luca, Lolli.

6.3.1 Computer networks

Involved people at OAB: Delpino, Di Luca.

During the past two years work has been done concerning all the relevant aspects of computers networks both at local (LAN) and geographical (MAN and WAN) level with the aim of testing the new generation protocols at OSI level 2 and 3 (pure ATM, ATM LAN emulation, IP next generation, OSPF). ATM in particular has been tested extensively due to the possibility of realizing multiple high speed connections on the same links, with static or dynamic band partition. This makes ATM attractive for all the environments with the need of multiple and multimedia data transfers (housekeeping data, scientific data, images in sequence, voice and video).

Delpino has drawn up the development model for the project of the new metropolitan research network of the Bologna town, which is based on a private ATM backbone at 622 Mbit/sec, connected with the ATM regional link, realized by means of radio frequency bridges, spanning all over the Emilia Romagna region, where the branch offices of the University of Bologna are located. On that model basis a hierarchical structure, formed by a top level independent backbone interfacing a large number of campus network, has been planned. The whole network will be operating before the end of the year 2001.

6.3.2 Web applications

Involved people at OAB: Delpino, Lolli.

Experience has been developed in the field of object programming, with particular reference at the Java language and C. The former in fact presents well definite advantages when one is interested in developing platform independent Web applications. The trend of extending the field of scientific applications usability further on the usual local area limits, making them available for the whole Internet community,

is presently well established. Nevertheless that implies the use of complex and sophisticated techniques for planning and programming new applications. On the other hand recently a new interest in applications using data organized inside a database raised up. The different techniques presently available for Web integration of both applications and databases have been studied and compared. A pilot project, LiREP, is being realized. LiREP is a web application for searching and retrieving astronomical data, images and spectra, from catalogs. It makes use of a web interface and back-end Java scripts to query the database holding catalogs.

6.4 Improvements in the accessory services

Involved people at OAB: Di Luca, Merighi.

Concerning accessory services improvements, two high-quality network printers HP 4050N (17 ppm, 600dpi, auto-duplex unit) have been bought. Their introduction has improved the distribution of printers in the building and decreased the work-load on the existing ones.

6.5 Loiano station

Involved people at OAB: Lolli, Gualandi

At the Loiano telescope all the computers have been connected on a 100 Mb lan, upgrading computer network cards and adding an Allied Telesys 10/100 Mb switch. A new network printer HP 4050 N has been added to the system.

6.6 Routine activities

Involved people at OAB: Di Luca, Gatti, Lolli, Madama, Montegriffo, Policastro.

Besides all the activities described till now, great part of the work of the computer center staff has been, as usual, devoted to routine activities such as hardware and software maintenance, failures management and user assistance.

Routine operations include:

- backup and user management on the central VMS computer
- backup and user management on computers dedicated to data-reduction
- supply of consumables (toners, paper for printers, magnetic supports for backup etc.)
- printer maintenance
- local network management
- administrative management of the computer center (software and hardware licenses, guarantees, purchases, contracts of maintenance)
- updates and new installations of application software for astronomical data reduction (MIDAS, IRAF etc.)
- management of the Observatory's WWW server

6.7 Other activities

Involved people at OAB: Bregoli, Lolli, Montegriffo.

The computer center staff has carried on other activities during 2001. Among them:

- Participation to ESO-VLT projects. Personnel of the computer center have collaborated in the ESO-VLT VIMOS project, developing software for data reduction and real time display. This work is now completed.
- Devolopment of original software for data analysis in digital photometry in crowded fields.
  In the crowded fields digital photometry subject, the CATAPACK program (management of photometric catalogues) has been developed. This software will provide tools for the handling and management of photometrical catalogues. These tools

have been designed to be simple in the use and portable to several OS (Compaq TrueUnix64, Linux, HP,Sun). These programs will be mainly used in the preparation and execution of scientific programs in the ItalFLAMES Consortium.
The core of the package is represented by two programs: *CataXcorr* amd *CataComb*.

- *CataXcorr* (Catalogues Cross Correlator) performs *cross-correlations* and roto-translations between an arbitrary number of catalogues. The program can map with high accuracy coordinate transformations between single coordinate systems and a common reference system, independently from any difference in scale, rotation and/or axis inversion, giving, as ouput, plate solutions and calibrations. The most interesting feature of CataXcorr is that it works in a complete automatic way. Solutions are found without any user interaction. This feature is achieved through a *pattern recognition algorithm*.
- *CataComb* (Catalogues Combiner) is a program that allows to combine an arbitrary number of catalogues, producing an output catalog containing the desired quantities. Objects in different input catalogues can be combined following a cross-correlation table generated by CataXcorr or by identifier. The main characteristic of CataComb is flexibility: the content of the output file is entirely controlled by the user through a syntax analysis algorithm that can understand arithmetic and logical expression of any complexity.

7 Library

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Involved people at OAB:

- *Library staff:* K. Alboresi, M. Marra.

The year 2001 saw our library make a considerable effort to gain full operativity for the new staff unit (contractor), which was obtained soon, and at the same time to carry on new projects, both at national and local level.

As for the second, our library had a primary role in the development of a national analysis of the use of scientific serials in the Italian astronomical libraries. This study led to the presentation of a paper at the national meeting of Italian astronomy librarians, held in Cagliari on 5-6th June, 2001. The final goal of this analysis, which is being completed at present, is to evaluate the possibility of starting national cooperation in buying astronomical serials, something which the official coming into force of INAF is expected to make easier.

At the beginning of the year, the web page of our library was completely renewed in content and graphics. This was made after a wide consultation of the scientific staff of both Astronomical Observatory and Department of Astronomy.

Books were bought in a considerable amount, on request of our researchers: a hundred books on behalf of the Astronomical Observatory and almost 60 for the professors of the Department of Astronomy (books were also received as gifts, for a total amount of $\sim 60\%$). These works are valuable both for being new and highly representative books in the field, and because of their considerable value: about 7,000 euros only for as much as the Observatory is concerned. All of these books were made available on the two national online catalogues (SBN and CUBAI) as well as inventoried in the new and improved inventory database which was provided at the beginning of the year. Other, less recent works were included in the national catalogue SBN, in a continuing effort to improve the www availability of the whole library stock. A special care was taken in maintaining the funcionality of the burglar alarm, for preventing thefts; selling conditions were also re-examined, for obtaining the highest possible saving from suppliers.

As for the ancient books collection, it was frequently consulted and some of the books have contributed to the exhibition "Il mondo in ordine", held in Bologna.

Serials - about 90 on the whole - were managed as usual, including the maintaining of the specific national catalogue; particular care was taken in making (and keeping) the majority of them available in on-line mode. A special and time-consuming initiative was the inventory check-up of past years of most serials, which took place during the summer.

Well-appreciated services have remained the document delivery service (almost 90 serial articles were sent to other libraries or requested for our researchers) and the inter-library book loan. Obviously enough, because of the considerably high number of students of the Astronomy degree course, the book loans are an important part of the daily routine. The registered users (local and from the outside) have increased to almost 800.

Serials binding, loan claims and training of part-time students employed in the library complete the list of other ordinary activities.

The staff is still composed by Marina Zuccoli (Chief librarian, Dept. of Astronomy), Pietro Candelaresi (Dept. of Astronomy), Monica Marra (Bologna Astronomical Observatory) and Katia Alboresi (Bologna A.O., contractor).

8 Outreach and educational activities

True colour image of the planetary nebula M27 (Dumb-bell Nebula), taken at Loiano (with BFOSC and CCD EEV) by Stefano Bernabei and the students Matteo Barnabè, Rodolfo Canestrari and Matteo Montemaggi. Exposure times were 120 s in R, 300 s in B, 100 s in V.

People involved at OAB:

- *Scientific staff:* B. Marano, G. Parmeggiani, V. Zitelli, R. Bedogni, A. Cappi, E. Ciotti, G. Clementini, A. D'Ercole, F.R. Ferraro, F. Fusi Pecci, R. Sancisi, F. Delpino.
- *Technical staff:* A. De Blasi, R. Di Luca.

Over the past years, the Bologna Astronomical Observatory (OAB) has been involved more and more in outreach and educational activities through: seminars, exhibitions and radio/tv programs. The growth of public interest toward astronomy and astrophysics has developed a stable partnership between the Observatory and other institutions like the Institute of Radio Astronomy (CNR Bologna), the amateur astronomers of Bologna and S. Giovanni in Persiceto (Bo).

Il Parco delle Stelle and *Con il laser tra le stelle* are two of the most successful activities started in 1996-1997 and enriched, during 2001, with the following events:

1. Col Favore del Buio
2. Con il laser tra le stelle
3. Le conquiste della ricerca spaziale
4. IperAstro
5. Il Notiziario Astronomico
6. Educational Courses:
   a) Conferenze della Specola
   b) L'Universo e l'origine della vita
   c) Galassie ed evoluzione dell'Universo
   d) Concorso Altri Mondi

8.1 Col Favore del Buio

People involved at OAB: Marano, Parmeggiani, Zitelli, De Blasi, Di Luca.

A few years ago, the collaboration between the OAB, the Assessorato Provinciale alla Cultura and the Loiano's council, led to the creation of *Il Parco delle Stelle*. With the collaboration of a group of astronomers, Parmeggiani and Zitelli, who are now responsible for this event, views of the most magnificent objects of our skies are organized with the 60-cm Telescope of Loiano built in 1936. Although this Telescope has often been modernized, it has kept its original main structure. After using the telescope, the visitors are invited to observe the skies without any instruments while a group of astronomers talk them through the various stars, planets, black holes and make themselves available to answer questions. Starting from 1998 new technologies have been introduced to the above program, the main ones being the multimedia-programs. Nowadays *Il Parco delle Stelle* is part of *Col Favore del Buio* and it works very closely with the Radio Astronomy Observatory of Medicina (Bo), the Astronomical Observatory of S. Giovanni in Persiceto (Bo), the conference hall of the Bologna Planetarium (primary school G. Carducci) and the Museum of Specola (Department of Astronomy). This event has been so successful that the schedule for the year 2001 has included 52 evening sessions with over 1.500 visitors (over 15.000 visitors for *Col favore del Buio*). The 60 cm telescope can be visited in the evenings only if reserved, the 1.52 m (G.D. Cassini) is open to public view on the first Saturday of the month and to schools in the morning if reserved.

8.2 Con il laser tra le stelle

People involved at OAB: Marano.

With the collaboration of Loiano's council, on August 13th, the Astronomical Observatory of Bologna has organized an evening dedicated to Perseid meteors known as Lacrime di S. Lorenzo. This event is called *Con il laser tra le stelle* and is leaded by prof. B. Marano, director of OAB until the end of 2001. For about 2 hours, with the help of a laser, prof. B. Marano taught the visitors how to orientate themselves in the dark sky.

8.3 Le conquiste della ricerca spaziale

People involved at OAB: Parmeggiani.

In year 2001 the OAB has organized a new training course for primary and high school teachers and students of astronomy. This event, called *Le conquiste della ricerca spaziale*, was sponsored by A.S.I. (Agenzia Spaziale Italiana), the Department of Astronomy of the University of Bologna and managed by Parmeggiani. The training course was planned in year 2001, it began on March 2002 and will finished on May. 32 teachers and a group of astronomy students are attending the courses. In year 2001 the astronomy journal of the S.A.It published the lessons of the training course of year 2000: *Leggere il cielo*. These articles explain, in a clear and simple way, the various astronomy topics and are available to the public.

8.4 IperAstro

People involved at OAB: Bedogni, Delpino. In collaboration with Zavatti and Delli Santi (Univ. Bologna).

Bedogni and Delpino are the authors of IperAstro, a modern course of Astronomy on CDrom. IperAstro is specialized for amateurs and high-school students, who are provided with several special understanding paths on the most relevant topics. Exercises, multiple answer tests with automatic correction and interactive sessions complete the course. Written in HTML IperAstro can be accessed using any last generation browser as a network or local (i.e. CDrom) applications.

8.5 Il Notiziario astronomico

People involved at OAB: De Blasi.

In the year 2001, the OAB has realized the website *Il Notiziario Astronomico* dedicated to teachers and students of the advanced Secondary Schools. During the last six months of the same year, over 2000 people visited these Internet pages. Every week De Blasi updates them with simple articles which discuss the main astronomical news. Through interviews with teachers and researches, *Il Notiziario*

Astronomico wants to be a simple but correct way to popularize the various astronomic topics.

8.6 Educational Courses

8.6.1 Conferenze della Specola

People involved at OAB: Parmeggiani.

On every first Wednesday of the month, at the Specola, the old Observatory of Bologna in the town center, there is a seminar on mayor astronomical topics. The audience is mainly composed by students of the advanced Secondary Schools. On average 70 people attend the conference.

8.6.2 L'Universo e l'origine della vita

People involved at OAB: Bedogni, Cappi, Ciotti, D'Ercole, Marano, Ferraro, Fusi Pecci, Zitelli.

Bedogni, Cappi, Marano were part of the teaching team in the course *L'Universo e l'Origine della vita*. This event was organized by the Astronomical Observatory of Bologna, in collaboration with the Department of Astronomy and the Faculty of Science of the University of Bologna. The number of people registered at the educational course was 55. This event was a part of the training course started in the autumn of the year 2000 and called *Leggere il cielo*.

8.6.3 Galassie ed evoluzione dell'Universo

People involved at OAB: Londrillo

As in the past few years, in 2001 Londrillo gave a course called *Galassie ed evoluzione dell'Universo* at the Primo Levi University (University of third age).

8.6.4 Concorso Altri Mondi

People involved at OAB: Parmeggiani

Altri Mondi is a competition organized by the Italian department of E.A.A.E. (European Association for Astronomy Education) in collaboration with Department of Astronomy of the University of Bologna, the Astronomical Observatory of Bologna, SAIt (Società Astronomica Italiana), AIF (Associazione per l'insegnamento della Fisica), ANISN (Associazione Nazionale Insegnanti di Scienze Naturali), Divisione Didattica della Società Chimica Italiana, CNR, ADA (Associazione Divulgazione Astrofisica), CIFS (Consorzio Interuniversitario per la Fisica Spaziale), ASI (Agenzia Spaziale Italiana), Alenia Spazio SpA, and Science Centre Extramuseum Torino.
Parmeggiani was part of the jury. This event was dedicated to students of Primary and Secondary Schools who were asked to send an essay on paper or ipertest about nine primary astronomical topics like: the life in the Universe, the evolution of life on Earth, the research of extra-terrestrial life, and so on. The jury received over 100 essays; the top 10 works got a cash prize, while the following 10 got an invitation to the ASI.

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The discovery in the WEB

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10 Observing Campaigns

Radio Telescopes

1. 1.4 GHz-PARKES SINGLE DISH: PI R.N. Manchester, Co-I: A.G. Lyne, **D'Amico, N.**, F. Camilo, V.M. Kaspi, I.H. Stairs, A. Possenti, M. Kramer, G. Hobbs, G.; *The Parkes multi-beam pulsar survey*; 80 days

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3. 1.4 GHz-PARKES SINGLE DISH: PI: B.C. Joshi, Co-I: M. Burgay, M. Kramer, R.N. Manchester, A.G. Lyne, A. Possenti, **D'Amico, N.**; *High latitude Parkes multi-beam pulsar survey*; 20 days

4. Australia Telescope Compact Array: PI: T.Venturi, Co-I: **Bardelli, S.**et al.; *Search for HI emission in the merging complex A3558* 12 hours, February 2002

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6. Very Large Array: PI: Murgia M., Co-I: **De Ruiter, H.R.**, et al. *Relic radio sources*, 18.5 hours

7. Very Long Baseline Array: PI: Morganti R., Co-I: **De Ruiter, H.R.**, et al. *HI in B2 radio galaxies*, 24 hours

8. Very Long Baseline Array: PI: T. Venturi, Co-I : **Comastri, A.**, F. Fiore, R. Morganti, S. Pellegrini *Probing the accretion process in the nucleus of the radio galaxy PKS 1333-33. An advection dominated accretion flow?* 16 hours; February 2001

HST

9. HST + WFPC2: PI: **Ferraro, F.R.**, Co-I: B. Paltrinieri, R.T. Rood, R. Buonanno, **Cacciari, C.**, R. O'Connell, B. Dorman; *UV Light from Old Stellar Populations: A Census of UV Bright Stars in 'Blue Tail' Globular Clusters*; 21 orbits, August 2000 - March 2001

10. HST + WFPC2: PI: **Stanghellini, L.**; *Planetary Nebulae in the LMC: a study on stellar evolution and Populations, Program 9120*; 28 orbits

11. HST + WFPC2: PI: Shaw, Co-I: **Stanghellini, L.**; *Survey of the LMC Planetary Nebulae, Program 9077*; 224 targets

12. HST-STIS: PI: C. Leitherer, Co-I: **Greggio, L.**, **Origlia, L.**, **Tosi, M.**; *The alpha-element/iron ratio in starburst populations*; 18 orbits, last observations: november 2001

13. HST-STIS: PI: F. Palla, Co-I: **Stanghellini, L.**, **Tosi, M.**; *The $^{12}C/^{13}C$ abundance ratio in NGC3242*; 5 orbits, march 2001

14. HST-ACS: PI: A. Aloisi, Co-I: **Tosi, M.**; *Searching for primeval galaxies: the promising case of SBS 1414+437*; 18 orbits presumably in 2002

15. HST ACS/WFC + ACS/HRC: PI: M. Rejkuba, Co-I: W. Harris, G. Harris, E. Peng, **Greggio, L.**; *Reaching the HB in NGC 5128: Deepest probe of a Giant Elliptical*; 24 primary orbits + 24 secondary orbits

ESO

16. ESO VLT2 + UVES: PI: R. Gratton, Co-I: ... **Bragaglia, A.**, ..., **Clementini, G.**...; *Distances, Ages, and Metal Abundances in Globular Cluster Dwarfs*; 18 nights, 25-30 August 2001 + 22-27 October 2001 + 6 nights July 2002

17. ESO VLT2 + UVES: PI: E. Pancino, Co-I: L. Pasquini, **Ferraro, F.R.**, **Bellazzini, M.**, V. Hill; *Solving the omega Centauri mistery, a cornerstone in the evolution of stellar systems. III: UVES high-resolution spectroscopy of stars in the anomalous RGB*; 13 hrs, April 2001

18. ESO VLT2 + UVES: PI: E. Pancino, Co-I: **Ferraro, F.R.**, L. Pasquini, V. Hill, **Bellazzini, M.**, L. Monaco; *Star formation history in omega Centauri: disentangling the age-metallicity degeneracy of the multiple populations*; 3 nights, 18-21 March 2002

19. ESO VLT2 + UVES: PI: **Ferraro, F.R.**, Co-I: **D'Amico, N.**, R. Gratton, Camilo, **Bragaglia, A.**, A. Possenti, E. Sabbi; *The true nature of the anomalous bright companion to the eclipsing millisecond pulsar in NGC6397*; 7 hrs, April 2002

20. ESO VLT1 + FORS1, PI: **Clementini, G.**, Co-I: **Bragaglia, A.**, E. Carretta, R. Gratton, L. Di Fabrizio, M. Maio; *The luminosity-metallicity relation for RR Lyrae's from variables in the bar of the Large Magellanic Cloud (68.D-0466)*; 3 nights, 20-21-22 December 2001

21. ESO VLT1 + FORS1: P.I.: **Clementini, G.**; Co-I: E.V. Held, I. Saviane, L. Di Fabrizio, Y. Momany, L. Rizzi; *The quest for old stellar populations in the Local Group: a search for RR Lyrae variables in NGC 6822*; 3 half nights (15-17/08/2001, 20-21/08/2001)

22. ESO VLT1 + FORS1: PI: E. Pancino, Co-I: **Ferraro, F.R.**, L. Pasquini, V. Hill, **Bellazzini, M.**, L. Monaco; *Star formation history in omega Centauri: disentangling the age-metallicity degeneracy of the multiple populations*; 9 hrs, October 2001

23. ESO VLT1 + FORS1: PI: **Ferraro, F.R.**, Co-I: E. Pancino, **Bellazzini, M.**, T. Richtler, M. Hilker, R.T. Rood; *The Mass Function of intermediate age Clusters in the Magellanic Clouds: a step toward the determination of the true nature of the IMF*; 12.5 hrs, October 2001

24. ESO VLT1 + FORS1: PI: L. Burderi, Co-I: G. Andreuzzi, **D'Amico, N.**, F. D'Antona, **Ferraro, F.R.**, G. Marconi, V. Testa, *Searching for the optical counterparts of new millisecond binary pulsars in 47 Tucanae*; 13 hrs, October 2001

25. ESO VLT + ISAAC: PI : Cimatti A., Co-I: Broadhurst T., Cristiani S., Daddi E., Fontana A., Gilmozzi R., Menci N., **Mignoli, M.**, Poli B., **Pozzetti, L.**, Renzini A., Saracco P., **Zamorani, G.** *The K<20 VLT Redshift Survey: constraining the high-z fraction* 5 hours (october 2001)

26. ESO VLT + FORS1: PI: Prandoni I., Co-I: **De Ruiter, H.R.**et al., *The ATESP deep sample* 7 hours service mode.

27. ESO VLT + FORS1 PI: F. Fiore Co-I: A. Baldi, S. Molendi, **Comastri, A.**, **Mignoli, M.**, M. Brusa, **Ciliegi, P.**, F. La Franca,

G. Matt, G.C. Perola, P. Severgnini, R. Maiolino, C. Vignali *Optical identification of faint hard HELLAS2XMM sources* 27 hours, service mode

28. ESO VLT + ISAAC: PI: A. Marconi, Co-I: D. Axon, A. Capetti, K. Horne, A. Robinson, M. Salvati, **Stirpe, G.M.** *Supermassive Black Holes in High Redshift Quasars* 30 hours, July-December 2001

29. ESO VLT + ISAAC: PI: **Comastri, A.**, Co-I : M. Brusa, **Ciliegi, P.**, **Mignoli, M.**, R. Maiolino, P. Severgnini, F. Fiore, F. La Franca, G. Matt, G.C. Perola, A. Baldi, S. Molendi, C. Vignali, **Pozzetti, L.** *What powers X-ray luminous optically quiet galaxies? A near infrared search for the AGN signature* 6 hours, service mode

30. ESO NTT + SOFI: PI: **Ferraro, F.R.**, Co-I: E. Pancino, **Bellazzini, M.**, Richtler, Hilker, R.T. Rood, G. Piotto; *Solving the omega Centauri mistery, a cornerstone in the evolution of stellar systems. I: deep high-resolution and IR photometry*; 2 nights, 4-6 May 2001

31. ESO NTT + SOFI: PI: **Origlia, L.**, Co-I: R. Maiolino, R. Cid Fernandez, E. Schmitt, T. Storchi-Bergmann; *Probing the starburst - AGN connection by means of near IR spectroscopy*; 3 nights, 9-13 July 2001

32. ESO NTT + SOFI: PI: M. Zoccali, Co-I: S. Cassisi, **Greggio, L.**, S. Ortolani, A. Renzini; *J,H,K CMD templates for old stellar populations*; 3 nights, P69

33. ESO NTT + SUSI2: PI: **Ferraro, F.R.**, Co-I: E. Pancino, **Bellazzini, M.**, **D'Amico, N.**, A. Possenti, E. Sabbi, *The true nature of the anomalous bright companion to the eclipsing millisecond pulsar in NGC6397*; 6 hrs, October 2001

34. ESO NTT + SUSI2: PI: **Ferraro, F.R.**, Co-I: **D'Amico, N.**, R. Gratton, Camilo, **Bragaglia, A.**, A. Possenti, E. Sabbi; *The true nature of the anomalous bright companion to the eclipsing millisecond pulsar in NGC6397*; 7 hrs, service, starting April 2002

35. ESO NTT + EMMI: PI: **Ferraro, F.R.**, Co-I: **D'Amico, N.**, R. Gratton, Camilo, **Bragaglia, A.**, A. Possenti, E. Sabbi; *The true nature of the anomalous bright companion to the eclipsing millisecond pulsar in NGC6397*; 4 hrs, service, starting April 2002

36. ESO NTT + SOFI: PI: M.Scodeggio, co-I: **Bardelli, S.**et al. *Infrared imaging of distant (z>* 0.8*) EIS candidate clusters* 2 nights, April 2001

37. ESO NTT + SOFI: PI: M.Scodeggio, co-I: **Bardelli, S.**et al. *Infrared imaging of distant (z>* 1.0*) EIS cluster candidates* 3 nights, January 2001

38. ESO NTT + SOFI: PI: M.Scodeggio, co-I: **Bardelli, S.**et al. *Infrared imaging of distant (z>* 1.0*) EIS cluster candidates* 2 nights, December 2001

39. ESO NTT + SOFI: *Infrared imaging of distant (z>* 1.0*) EIS cluster candidates* PI: M.Scodeggio, co-I: **Bardelli, S.**et al. 2 nights, September 2002

40. ESO NTT + SOFI: PI : Le Fevre O., Co-I: Arnaboldi, Cuby, Garilli, Iovino, Maccagni, McCracken, Mazure, Picat, Saracco, Scaramella, Scodeggio, Tresse, Vettolani, Zanichelli, **Zamorani, G.***A deep J and Ks imaging survey: preparation to the VIRMOS Deep Redshift Survey* 2 nights September 2001

41. ESO NTT + SOFI: PI : Krautter Co-I: ..., **Zamorani, G.**, ... *Public Imaging Survey* 2 hours (march 2002) + 8 nights (april 2002)

42. ESO NTT + SOFI: PI : Krautter Co-I: ..., **Zamorani, G.**, ... *Public Imaging Survey* 3 nights, September 2002

43. ESO 3.6m + EFOSC: PI : Matute I., Co-I: La Franca F., Gruppioni C., Pozzi F., Lari C., **Zamorani, G.**, Franceschini A. *Looking for faint, IR selected type 2 AGNs at high redshift* 2 nights, November 2001

44. ESO 3.6m + EFOSC2: PI : Matute I., Co-I: La Franca F., Gruppioni C., Pozzi F., Lari C., **Zamorani, G.**, Franceschini A., Oliver S., *The evolution of the milliJansky 15 micron populations* , 2 nights, September 2002

45. ESO 3.6m + TIMMI2: PI: **Origlia, L.**, Co-I: **Ferraro, F.R.**, M. Catelan, R.T. Rood: *Circumstellar dust in Galactic globular clusters: towards an empirical determination of mass loss rates in Population II giants*; 3 nights, 5-8 July 2001

46. ESO 3.6m + EFOSC2: PI: **De Ruiter, H.R.**, Co-I: many others. *The search for distant clusters containing bent radio sources* 17-21 November 2001 (four half nights).

47. ESO 3.6m + EFOSC2: PI. Maurogordato S., Co-I. Benoist C., **Cappi, A.**, Ferrari C. et al. *Star Formation within merging Clusters of Galaxies: Multi-Object Spectroscopy*, 1 night, April 2001, 1 night, September 2001

48. ESO 3.6m + EFOSC2: PI F. Fiore, Co-I: A. Baldi, S. Molendi, **Comastri, A.**, C. Vignali, F. La Franca, G. Matt, *Optical identification of hard X-ray selected XMM-Newton sources* 3 nights, August 2001

49. ESO 2.2m + WFI: PI: Arnaboldi M., Co-I: de Martino D., Garilli B., Guzzo L., Le Fevre O., Maccagni D., Mazure, McCracken H., Picat, Scaramella R., Vettolani G., **Zamorani, G.***A deep + shallow U imaging survey: preparation to the VIRMOS Deep redshift Survey*; 3 nights (march 2001) + 2 hours (august 2001) + 30 hours (october 2001)

50. ESO 2.2m + WFI: PI: **Ferraro, F.R.**, Co-I: E. Pancino, **Bellazzini, M.**, B. Paltrinieri, R.T. Rood, L. Monaco, **Bragaglia, A.**; *Large population studies of globular clusters (68.D-0212)*; 30 hrs, service

51. ESO - 2.2m + WFI PI : Franceschini A., Co-I: Vettolani, Held, Lonsdale, **Zamorani, G.**, Rowan-Robinson, Smith, Rizzi, **Ciliegi, P.**, La Franca, Oliver, Perez-Fournon, Gruppioni, Prouton, Rodighiero, Berta, Matute *An ESO-SIRTF wide-area imaging survey (ESIS), Targeting the history of cosmic transformations of baryons in stars and active nuclei*; 50 hours, October 2001

52. ESO - 2.2m + WFI PI : Krautter Co-I: ..., **Zamorani, G.**, ... *Public Imaging Survey* 14 hours, November 2001

53. ESO - 2.2m + WFI PI : Arnaboldi Co-I: Garilli, Guzzo, Le Fevre, Maccagni, Mazure, Picat, Radovich, Ripepi, Scaramella, Vettolani, **Zamorani, G.***A deep + shallow U imaging survey: preparation to the VIRMOS Deep redshift Survey* 40 hours, April 2002

54. ESO - 2.2m + WFI PI : Krautter Co-I: ..., **Zamorani, G.**, ... *Public Imaging Survey*, 30 hours, April 2002

55. ESO - 2.2m + WFI PI.: Benoist C., Co-I. **Cappi, A.**, Ferrari C., Maurogordato S., Slezak E. et al., *Analysis of a merging clusters of*

Galaxies: deep multicolor wide-field imaging of A521 4.5h, October 2001

56. ESO - 2.2m + WFI P.I.: Maurogordato S., Co-I: Benoist C., **Cappi, A.**, Ferrari C. et al., *Dynamics and star-formation within merging clusters of galaxies: multi-color imaging of A1750* 6h, 2002A, 69.A-0673

57. ESO 1.5m + FEROS: PI: **Bragaglia, A.**, Co-I: **Tosi, M.**, E. Carretta, R. Gratton; *High resolution spectroscopic study of old open clusters as tracers of galactic chemical evolution (67.D-0018)*; 3 nights, 23-25 April 2001

58. ESO 1.5m Danish + DFOSC: P.I.: **Clementini, G.**; CoI-: **Bragaglia, A.**, E. Carretta, F. Castelli, R.G. Gratton, L. Di Fabrizio, C. Maceroni, M. Marconi; *Distance indicators in the LMC: RR Lyrae variables, red clump stars, and eclipsing binaries*; 2 nights, 23-24/01/2001

59. ESO 1.5m Danish + DFOSC: PI: **Tosi, M.**, Co-I: **Bragaglia, A.**, G. Marconi; *Photometry of old open clusters to trace the evolution of the Galactic disk (67.D-0014)*, 3 notti, 15-17 maggio 2001

60. ESO 1.5m Danish + DFOSC: PI: **Cacciari, C.**, Co-I: Catelan M., **Bellazzini, M.**; *R Lyrae stars in the 2nd-parameter globular clusters NGC362 and NGC1904*; 4 nights, 14-18 November 2001

TNG

61. TNG + SARG: PI: **Bragaglia, A.**, Co-I: **Tosi, M.**, E. Carretta, R. Gratton; *Metal abundances of old open clusters as tracers of galactic chemical evolution*; 3 nights, October 2001

62. TNG + SARG: P.I.: **Clementini, G.**, Co-I: **Cacciari, C.**, **Fusi Pecci, F.**; *The Baade-Wesselink method on RR Lyrae variables in M3*; 3 nights, 21-23/05/2001

63. TNG + LRS: PI: **Cacciari, C.**, Co-I: **Bragaglia, A.**, A. Bozzoni, T. Kinman; *RR Lyrae and BHB stars at the North Galactic Pole*, 3 nights, April 2001 + 4 nights February and April 2002

64. TNG + DOLORES & NICS: PI: **Ferraro, F.R.**, Co-I: **Bellazzini, M.**, **Cacciari, C.**, **Origlia, L.**, E. Pancino, E. Oliva; *Getting accurate distances to Local-Group Galaxies*; 6 nights, March-April 2001

65. TNG + DOLORES & NICS: PI: **Ferraro, F.R.**, Co-I: **Bellazzini, M.**, **Origlia, L.**, L. Monaco, E. Pancino, E. Oliva, **Cacciari, C.**, *Getting accurate distances to Local-Group Galaxies*; 6 nights, September 2001

66. TNG + NICS: PI: **Origlia, L.**, Co-I: E. Oliva, **Ferraro, F.R.**, A. Buzzoni; *Metallicity, alpha-elements and the formation history of elliptical galaxies*; 3 nights, June 2001

67. TNG + NICS: PI: **Ferraro, F.R.**, Co-I: **Origlia, L.**, E. Pancino, R.T. Rood, V. Testa; *Multi-band population studies of Galactic Globular Clusters: Infrared Luminosity Functions*, 3 nights, June 2001

68. TNG + NICS: PI: **Ferraro, F.R.**, Co-I: **Origlia, L.**, L. Monaco, E. Pancino, R.T. Rood, V. Testa; *Multi-band population studies of Galactic Globular Clusters: Infrared Luminosity Functions*; 2 nights, August 2001

69. TNG + NICS: PI: R.M. Gonzalez Delgado, Co-I: **Origlia, L.**, R. Cid Fernandes, T. Heckman, E. Perez, H. Schmitt, T. Storchi-Bergmann; *Probing the Starburst-AGN connection at the Near-Infrared*; 4 nights, August 2001

70. TNG + OIG: PI: **Ferraro, F.R.**, Co-I: L. Monaco, E. Sabbi, E. Pancino, B. Paltrinieri, V. Testa; *A photometric search for interacting binaries in moderate-density GGCs*; 1 night, May 2002

71. TNG + DOLORES PI: F. La Franca, Co-I : **Comastri, A.**, F. Fiore, Severgnini P., Molendi S., Vignali C., Matt G. *Optical identification of hard X–ray selected XMM–Newton sources* 2 nights; September 2001

72. TNG + DOLORES PI: F. La Franca, Co-I : **Comastri, A.**, F. Fiore, F. La Franca, F. Nicastro, A. Fruscione, S. Molendi, P. Severgnini, R. Maiolino *Optical identification of hard (2-10 keV) X-ray HELLAS2XMM sources* 3.5 nights; March 2002

LOIANO

73. LOIANO 1.52m: P.I.: **Clementini, G.**, Co-I: **Tosi, M.**, **Merighi, R.**, **Bragaglia, A.**, Di Fabrizio L.; *Fotometria CCD di RR Lyrae "anomale"*; 10 nights, 19-23/03/2001, 22-26/04/2001

74. BeppoSAX PI: S. De Grandi, Co-I: **Bardelli, S.**, **Cappi, A.**, **Zucca, E.**et al.; *The dynamics of merging clusters in Cor Bor supercluster*, 250 ks; August 2000 and January 2001

75. XMM-*Newton* PI: **Comastri, A.**, Co-I: Cimatti A., Daddi E., Roetgering H.J., Andreani P., Vignali C., Fiore F., Antonelli L.A. *Searching for dust obscured AGN in Extremely Red Objects* 50 ks; August 2001

76. XMM-*Newton* PI: **Comastri, A.**, Co-I: Vignali C., Fiore F., Cappi M., Palumbo G.C., Costantini E., Laor A., Mineo T. *X–ray spectroscopy at the "quasar era"* 60 ks; December 2001

77. XMM-*Newton* PI: Ettori S., Co-I: **Bardelli, S.**, **Zucca, E.**et al.; *Spatially resolved spectroscopy of merging clusters in the Shapley Concentration* 45 ks: December 2001 and January 2002

78. *Chandra* PI: S. Pellegrini, Co-I: **Comastri, A.**, G. Fabbiano, F. Fiore, R. Morganti, G. Trinchieri, T. Venturi, C. Vignali *Origin of the hard emission in the optically inactive elliptical galaxy IC 4296 from high resolution X-ray and radio observations* 25 ks in AO3

79. *Chandra* PI: F. La Franca, Co-I : A. Baldi, **Comastri, A.**, G. Matt, S. Molendi, F. Fiore C. Perola, C. Vignali *A cheap complete wide bright survey* 18 ks in AO3

80. *Chandra* PI: G. Brunetti, Co-I: M. Bondi, **Comastri, A.**, G. Setti *Inverse Compton scattering in powerful radio galaxies: constraining the electron spectrum* 60 ks in AO3

81. *Chandra* PI: M. Bondi, Co-I: G. Brunetti, **Comastri, A.**, G. Setti *Unveiling the powerful quasar hidden in the nucleus of the FR II radio galaxy 3C 265* 60 ks in AO3

Miscellaneous

82. KeckII + NIRSPEC: PI: R.M. Rich, Co-I: S.M. Castro, **Origlia, L.**; *Abundances of Bulge and Galactic Center cluster stars*; 2 nights, 22-23 June 2001

83. KeckII + NIRSPEC: PI: R.M. Rich, Co-I: **Origlia, L.**; *Abundances of Bulge and Galactic Center cluster stars*; 1.5 nights, 12-14 July 2002

84. CFHT, Cfh12K, P.I. Benoist C., Co.I.: **Cappi, A.**, Ferrari C., Maurogordato S., et al., *Deep multicolor wide-field imaging of Abell 521*, 4 hours, 2001B

85. CFHT, Cfh12K, P.I. Benoist C., Co-I: **Cappi, A.**, Ferrari C., Maurogordato S., et al. *Multicolor wide field imaging of merging clusters*, 8hours, 2002A

11 Position held in working groups and science policy committees

- **Cacciari, C.**:

  – Telescopio Nazionale Galileo (TNG) Time Allocation Committee: member
  – SOC for the IAU Commission 27 Variable Stars: member
  – PI of the ITAL-FLAMES Consortium (Bologna, Trieste, Cagliari and Palermo Observatories) for the FLAMES instrument

- **Ciotti, L.**:

  – Bologna Astronomical Observatory: member of the Board
  – Scuola Normale Superiore di Pisa: Visiting Astronomer and Lecturer of *Dynamical models in astrophysics* (since 1997)

- **Comastri, A.**:

  – ESA : XMM–*Newton* User Group : member
  – ESA : XEUS (X-ray Evolving Universe Spectroscopy) Astrophysics Working Group : member
  – Bologna University - teacher of the *Space Physics* course for the academic year 2001-2002

- **Delpino, F.E.**

  – Comitato Scientifico di Sviluppo per i Servizi Informatici dell'Università di Bologna: member
  – Commissione per la Rete ALMAnet dell'Università di Bologna : member
  – Comitato per lo Sviluppo ed il Coordinamento della Rete della Ricerca Regionale: member
  – Network Security Group of ALMAnet - Università di Bologna:

member
– ALMAnet-G Project (the new broad band academic network): chairman
– Progetto Immatricola and WebPay : project manager

- **De Ruiter, H.R.**:

  – Expert evaluator of the European Union Training and Research Networks.
  – Local coordinator of the European Union network "CERES" (until August 2001)
  – Local scientific coordinator of the European Union "Information Society Technologies (IST)" programme Cosmolab (3D visualisation techniques in Astronomy) (from September 2001).

- **Ferraro, F.R.**:

  – ST-ECF User Committee: member
  – ESO : Observing Programmes Committee (OPC): panel D1: member
  – OAB team ITAL-FLAMES Consortium :member
  – Bologna University - teacher of *Stellar Evolution* class for the academic year 2001-2002

- **Fusi Pecci, F.**:
  – ESO-OPC: member at large
  – CNAA: member of the Board
  – Cagliari Astronomical Observatory: director
  – Padova Astronomical Observatory: member of the Board
  – CAISMI-TIRGO-CNR Science Committee: member
  – TNG instruments: coordinator.

- **Marra, M.**

  – Member of the working group on serials among the Italian astronomy librarians

- **Origlia, L.**:

  – TNG TAC member

- **Tosi, M.**:

  – member of Local Late Galactic Evolution group at International Space Science Institute - ESA (since 1998)
  – Interstellar Pathfinder mission (NASA proposal) Associate Scientist (since 1998)

- **Greggio, L.**:

  – External referee for TNG AOT 4 and AOT 5

- **Sancisi, R.**:

  – ESO Scientific Technical Committee : member

- **Stanghellini, L.**:

  – Affiliated to the Astrophysics Division, Space Science Department of ESA
  – Member of the Science Policies Division, Space Telescope Science Institute
  – Member of the Director's Leadership Forum (DLF), Space Telescope Science Institute
  – Head of the working group on the scientific environment (DLF)

- **Zamorani, G.**:

  – ESO : VIRMOS Science Team : member
  – ESO: Survey Working Group : member

– BeppoSAX: Science Steering Committee (1999 - 2002) : member
– INAF: Comitato di Consulenza Scientifica: chairman
– Bologna Astronomical Observatory : member of the Board
– Arcetri Astrophysical Observatory : member of the Board

- **Zitelli, V.**:

– TNG: Working group on site testing: member
– Bologna University - teacher of the *Theory and Techniques for imaging data analysis* course for the academic year 2001-2002

- **Zucca, E.**:

– XLV National Meeting of SAIt: SOC member and LOC chair

12 Organization of Workshops and Schools

1. *Nuovo viaggio nel cosmo: prospettive scientifiche e organizzative dell'astronomia italiana alla luce delle nuove strumentazioni*
   XLV Congresso Nazionale della Società Astronomica Italiana
   Bologna, May 2-5, 2001
   Organized by: Osservatorio Astronomico di Bologna, Dipartimento di Astronomia Università di Bologna, CNR-IRA, CNR-TESRE, CNAA, ASI, SAIt
   SOC: Bonoli, F., Capaccioli, M., Giacomelli, G., Mandolesi, N., Marano, B., Vettolani, G., **Zucca, E.**
   LOC: **Zucca, E.**(chair), Brighenti, F., Brunetti, G., Kelm, B., Malaguti, G., Prandoni, I.

2. *Scuola Nazionale INAF/INFN di Astroparticelle: Cosmologia e Particelle elementari*
   Bertinoro, October 21-26, 2001
   Organized by: INAF-Osservatorio Astronomico di Bologna and INFN
   SOC: Bottino, A., Lucchin, F., Marano, B., Masiero, A., Matarrese, S., Remiddi, E.,
   LOC: Brusa, M., **Cappi, A.**, Casadei, D.,

13 Colloquia and visiting astronomers

13.1 Colloquia at the Observatory

1. January 11, 2001: **Marcel Clemens** (Astrophysics Group, Cavendish Laboratory, Cambridge, UK) *"The inter-stellar medium in interacting galaxies"*

2. January 16, 2001: **Victor Debattista** (Astronomisches Institut, Universität Basel, CH) *"Bar pattern speeds and the dark matter content of disk galaxies"*

3. January 18, 2001: **Bianca Poggianti** (Osservatorio Astronomico di Padova) *"Galaxies in dense environments"*

4. January 25, 2001: **Alessandro Braccesi** (Dipartimento di Astronomia, Università di Bologna) *"Quantistica, uomo, natura: riflessioni sul tema"*

5. February 05, 2001: **Henry Mc Cracken** (Laboratoire d'Astrophysique de Marseille, France) *"100000 galaxies, 1sq degree: a precise measurement of galaxy clustering at $I_{AB} \sim 25$"*

6. February 08, 2001: **Gabriele Giovannini** (Dipartimento di Fisica, Università di Bologna) *"Proprietà su scala del parsec di un campione di radio galassie"*

7. February 15, 2001: **Thijs van der Hulst** (Kapteyn Astronomical Institute, Groningen, NL) *"ISO studies of the ISM in late type galaxies"*

8. February 22, 2001: **Emanuele Giallongo** (Osservatorio Astronomico di Monteporzio, Roma) *"Evoluzione cosmologica delle galassie"*

9. March 07, 2001: **Tino Oliva** (Centro Galileo Galilei, Santa Cruz de La Palma, TF - Spain) *"TNG: stato attuale, capacità osservative e prospettive a breve termine"*

10. March 15, 2001: **Andrea Ferrara** (Osservatorio Astrofisico di Arcetri, Firenze) *"Galaxy formation and reionization: unveiling the end of dark ages"*

11. March 22, 2001: **Alessandro Marconi** (Osservatorio Astrofisico di Arcetri, Firenze) *"Supermassive Black Holes in galaxy nuclei"*

12. March 29, 2001: **Stefano Borgani** (INFN - Sezione di Trieste) *"Cosmologia con ammassi di galassie"*

13. April 05, 2001: **Orazio Bendinelli** (Dipartimento di Astronomia, Università di Bologna) *"Una parametrizzazione delle cuspidi di luce al centro delle galassie: confronto con osservazioni HST e modelli"*

14. April 10, 2001: **Anna Pasquali** (ESO/ST-ECF) *"Spectrophotometry with HST Advanced Camera for Surveys"*

15. April 19, 2001: **Bepi Tormen** (Dipartimento di Astronomia, Università di Padova) *"Ammassi di galassie: 'osservare' le simulazioni"*

16. May 08, 2001: **Juan Antonio Belmonte** (Instituto de Astrofisica de Canarias, Spain) *"Heaven's stones: discussions on the astronomy of the megalithic phenomena"*

17. May 10, 2001: **Cesare Chiosi** (Dipartimento di Astronomia, Università di Padova) *"Formation and evolution of elliptical galaxies"*

18. May 17, 2001: **Enrico Massaro** (Istituto Astronomico, Università di Roma "La Sapienza") *"Osservazioni nella banda X di pulsar gamma con BeppoSAX"*

19. May 24, 2001: **Luca Ciotti** (Osservatorio Astronomico di Bologna) *"The $M_{bh} - \sigma$ relation as a constraint on the formation of elliptical galaxies"*

20. May 29, 2001: **Regina E. Schulte-Ladbeck** (Dept. of Physics & Astronomy, University of Pittsburgh, USA) *"Old stars in Young Galaxies?! The Nature of Blue Compact Dwarfs"*

21. May 31, 2001: **Roberto Capuzzo Dolcetta** (Dipartimento di Fisica, Università di Roma "La Sapienza") *"Evoluzione del sistema di ammassi globulari in galassie ellittiche"*

22. June 07, 2001: **Micol Bolzonella** (Istituto di Fisica Cosmica "G.Occhialini", Milano) *"HDFs Luminosity Functions beyond the spectroscopic limit: clues on galaxy formation and evolution"*

23. June 14, 2001: **Raffaele Gratton** (Osservatorio Astronomico di Padova) *"Metal abundances of Turn-Off and subgiant stars in Globular Clusters: the impact on stellar evolution, on distance and age determination"*

24. June 21, 2001: **Antonaldo Diaferio** (Dipartimento di Fisica Generale, Università di Torino) *"Stime di massa in regioni esterne di ammassi di galassie"*

25. June 28, 2001: **Francesca Boffi** (Space Telescope Science Institute, Baltimore, USA) *"La supernova di Tipo Ia SN 1998aq e la costante di Hubble"*

26. July 05, 2001: **Manuela Zoccali** (European Southern Observatory) *"The Galactic Bulge and its Globular Clusters with HST"*

27. September 27, 2001: **George Wallerstein** (Astronomy Department, University of Washington, USA) *"What is Omega Cen: A captured galaxy or just a large globular cluster?"*

28. October 02, 2001: **Paulo Cesar C. Freire** (Arecibo Radio Observatory, Puerto Rico) *"The pulsars in 47 Tuc"*

29. October 11, 2001: **Ulrich Klein** (Radioastronomisches Institut, Universitat Bonn) *"Dwarf galaxies: small but enlightening"*

30. October 25, 2001: **Roberto Maiolino** (Osservatorio Astrofisico di Arcetri, Firenze) *"Nuclei Galattici Attivi oscurati e galassie Starburst"*

31. November 15, 2001: **Frazer Owen** (The National Radio Astronomy Observatory (NRAO), USA) *"The Deep Abell 2125 Radio Field: Star-formation and AGNs In and Out of Rich Clusters"*

32. December 20, 2001: **Massimiliano Bonamente** (Department of Physics, University of Alabama, Huntsville, USA) *"Eccesso di radiazione EUV e soft-X in ammassi di galassie"*

13.2 Additional visiting astronomers at the Observatory

1. **A. Aloisi** (STScI, Baltimore USA) January 2001
2. **R. Swaters** (DTM, Washington DC, USA) February 2001
3. **L. Burderi** (Roma Observatory) March and September 2001
4. **M. Catelan** (Pontificia Universidad Catolica de Chile) June 2001
5. **A. Robinson** (Univ. of Hertfordshire) July 2001
6. **D. Axon** (Univ. of Hertfordshire) July 2001
7. **J. Bregman** (Ann Arbor) July 2001
8. **M. Corwin** (Univ. of North Carolina, USA) July 2001
9. **T. Di Salvo** (Faculty of Science of the University of Amsterdam) September 2001
10. **M. Rich** (UCLA) October 2001
11. **U. Klein** (Bonn University) October 2001
12. Several guests during the **VIRMOS Science Meeting** November 2001
13. **R.T. Rood** (University of Virginia, USA) November 2001
14. **A.G. Lyne** (Jodrell Bank Observatory) November 2001
15. **S. Ettori** (ESO) December 2001

14 "Laurea" thesis at the Bologna Observatory

14.1 "Laurea" at the Astronomy Department

March 19, 2001:

1. **Angeretti Luca**, *Effetti di selezione in brillanza superficiale nella rivelazione di galassie deboli: teoria e confronto con un modello di evoluzione in luminosità* (Marano B., **Pozzetti, L.**, **Zamorani, G.**)

2. **Annibali Francesca**, *Storia della formazione stellare nella galassia nana NGC 1705* (Marano B., **Tosi, M.**)

3. **Monelli Matteo**, *Applicazione del codice Starfinder a immagini HST "dithered" della galassia nana NGC 1705 e confronti con i risultati precedenti* (Bendinelli O., **Tosi, M.**)

4. **Sarti Gessica** *Caratteristiche morfologico-dinamiche di un campione completo di tripletti di galassie* (Focardi P., **Zitelli, V.**)

July 20, 2001:

5. **Di Cristo Ciro**, *Risonanze orbitali in sistemi non collisionali: evaporazione stellare da galassie ellittiche con oscillazioni interne* (Focardi P., **Ciotti, L.**)

October 12, 2001:

6. **Fici Leonardo** *"Timing" delle millisecond pulsar nell'ammasso globulare NGC 6752* (Fanti R., **D'Amico, N.**, Possenti A.)

7. **Perina Sibilla**, *Fotometria infrarossa di una campione di ammassi globulari con il telescopio nazionale Galileo* (Battistini P., **Ferraro, F.R.**)

8. **Riciputi Andrea**, *Una nuova famiglia di modelli per galassie ellittiche con anisotropie e buco nero centrale* (Marano B., **Ciotti, L.**)

December 21, 2001:

9. **Calabrese Emanuela**, *Un campione di radiosorgenti sub-millijansky: proprietà fotometriche nelle bande ottiche e nel vicino e medio infrarosso* (Marano B., **Ciliegi, P.**)

10. **Maio Marcella**, *Le RR Lyrae nella Grande Nube di Magellano: un primo passo per la definizione della scala delle distanze astronomiche* (Marano B., **Clementini, G.**)

11. **Rossetti Alessandra**, *Profili di densità e temperatura dell'ICM e stime di metallicità* (Pellegrini S., **Ciotti, L.**)

March 15, 2002:

12. **Avolio Serena**, *Proprietà statistiche di ammassi di galassie selezionate in banda X* (Marano B., **Zucca, E.**, **Bardelli, S.**)

13. **Cancelliere Francesco**, *Spettroscopia e variabilità in banda X di galassie di Seyfert* (Marano B., **Comastri, A.**)

14. **Valenti Elena**, *Ricerca di variabili RR Lyrae negli ammassi globulari NGC 6304 e Arp 2* (Battistini P., **Bellazzini, M.**, **Cacciari, C.**)

14.2 "Laurea" at the Physics Department

July, 2001:

15. **Urbinati Nicola**, *Eclipse Mechanisms in binary millisecond pulsars: the case of PSR J1740−5340*, (Giovannini G., Possenti A., **D'Amico, N.**)

16. **Cerutti Rossella**, *X-ray emission from neutron stars: correlation with the rotational energy loss*, (Colpi M., Mereghetti M., Possenti A.)

15 PhD theses at the Bologna Observatory

1. **Marcella Brusa**, *Physics and evolution of hard X–ray selected sources*, in progress (**Comastri, A.**and Marano B. advisors)

2. **Marta Burgay**, *The Parkes High Latitude Pulsar Survey*, in progress (**D'Amico, N.**Possenti, A. and Fanti R. advisors)

3. **Filippo Fraternali**, *The gaseous halo of the spiral galaxy NGC2403*, completed (**Sancisi, R.** and Fanti R. advisors)

4. **Lorenzo Monaco**, *Stellar populations in the Galactic Halo*, in progress (**Ferraro, F.R.**and Battistini P. advisors)

5. **Carlo Nipoti**, *Phase space density, merging and the fundamental plane of elliptical galaxies*, in progress (**Ciotti, L.**, **Londrillo, P.** and Setti G. advisors)

6. **Elena Pancino**, *The surprisingly stellar population in ω Centauri*, in progress (**Ferraro, F.R.** and Bartolini C. advisors)

7. **Francesca Pozzi**, *Survey IR ELAIS: analysis and interpretation*, completed (**Ciliegi, P.**, Gruppioni, C. and Fanti C. advisors)

8. **Piero Ranalli**, *High Energy Emission from Starburst Galaxies*, in progress (**Comastri, A.**and Setti G. advisors)

16 Post-Doctoral, Post-Laurea fellowship and Contracts

1. **Aiudi Rachele**, Post Laurea contract
2. **Angeretti Luca**, Post Laurea contract
3. **Annibali Francesca**, Post Laurea contract
4. **Baldacci Lara**, Post Laurea contract
5. **Di Fabrizio Luca**, Post Laurea contract
6. **Fici Leonardo**, Post Laurea contract
7. **Lanzoni Barbara**, Post-Doctoral fellow
8. **Silvia Galleti**, Post Laurea contract
9. **Possenti Andrea**, Post-Doctoral fellow
10. **Rossetti Emanuel**, software development contract
11. **Sabbi Elena**, Post Laurea contract
12. **Urbinati Nicola**, Post Laurea contract
13. **Vignali Cristian**, Post-Doctoral contract