Osservatorio Astronomico
di Bologna

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Presentation

The *Osservatorio Astronomico di Bologna* is one of the twelve Italian Observatories, operating under the supervision of the Ministry for University and Scientific and Technological Research. The Ministry provides most of the financial resources which make our activity possible.

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

- galactic and stellar evolution studies and their cosmological implication
- study of the structure, evolution and distribution of galaxies, clusters and AGN and their contribution to the cosmological background
- 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 *Universitá 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 (VIRMOS, ISO-ELAIS, ESO slice project, K20 redshift survey).

Finally between the last months of 1998 and the first half of 1999 the *Osservatorio Astronomico di Bologna* and the *Dipartimento di Astronomia* moved to the new building in Via Ranzani 1. The definition of the new logistic for the hardware, the re-wiring of the computer network and the re-installation of all the computers required a strong effort to the computer center staff.

This report has been prepared by **Paolo Ciliegi**, **Lucia Pozzetti** and **Monica Marra**, with the collaboration of Michele Bellazzini, Luca Ciotti, Antonio De Blasi, Hans De Ruiter, Roberto Di Luca,

Monica Ferrarini, Marco Lolli, Roberto Merighi, Cristian Vignali and Valentina Zitelli.

Bruno Marano

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Contents

1 Stars and Stellar Populations

The Globular Cluster NGC 6093 with the Hubble Space Telescope. This high-resolution image was created from 2 separate pointings of HST. One WFPC2 data set was obtained by **Ferraro, F.R.***(OAB) B. Paltrinieri, R.T. Rood, B. Dorman who study blue stragglers. The other data set was acquired by M. Shara, D. Zurek and L. Drissen to search for dwarf novae. (Image Credit: Hubble Heritage Team AURA/STScI/NASA)*

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:* L. Di Fabrizio, M. Messineo, A. Possenti.

The evolution of stars and stellar systems under many points of view is an 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 1999 has been organized in a few main sections to provide a very general view: 1. The chemical evolution of the Galaxy, 2. Galactic Globular clusters, 3. Globular Clusters Systems, 4. Nearby Galaxies, 5. RR Lyrae Variable stars, 6. Eclipsing binaries, 7. Planetary Nebulae, 8. Pulsars, 9. Integrated Light of Early Type Systems.

1.1 The chemical evolution of the Galaxy

1.1.1 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 and the models computed by our group are among the most successful ones. There are, however, a number of open questions on the evolution of the Galaxy, which still require further studies. Some of these issues are being examined in detail at the Bologna Observatory. In 1999, we have essentially concentrated on the feedback between stellar nucleosynthesis and chemical evolution (Tosi 2000a), on the evolution of the abundance gradients and on the cosmological application of Galactic chemical evolution models.

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

Involved people at OAB: Bonifazi, Bragaglia, Tosi.

Open clusters (OC's) are ideal objects to trace the Galactic disk: they are found in all disk regions, cover a large interval in age (from a few million years to about 10 Gyr) and in metallicity ([Fe/H] from -1 to more than solar). Hence, they are excellent tools to understand the evolution of our Galaxy from both the chemical and structural points of view, also because OC's are perhaps the only disk objects whose ages and metallicities can be precisely measured (Bragaglia et al. 2000a,b).

As an example of the importance of OC's we may look at the history of the Galactic chemical evolution: many of the existing models are able to reproduce rather well the present-day situation, but differ significantly (Tosi 2000a) 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 sample of open clusters at various galactic locations and covering a wide range in age and metallicity. Our goal is to study at least 30 OC's covering a wide range in the observed properties. Age, distance modulus, reddening and approximate metallicity of the clusters are derived from their Color-Magnitude Diagrams (CMDs) using the synthetic CMD technique and further constrained by the observed luminosity functions. It must be emphasized that this analysis requires a high degree of homogeneity, since the use of literature values can lead to a confusing picture: e.g. ages, derived with different techniques/isochrones, may not only be uncertain in absolute value, but also in ranking. Precise and homogeneous elemental abundances are determined from high resolution spectroscopy; note that only about 18 of the about 80 old OC's have ever been studied with high resolution spectroscopy, and only a handful have abundances of elements other than iron. This research is in collaboration with Marconi (OAR), Carretta and Gratton (OAPd).

So far we have studied in detail the CMDs of about 10 OC's (NGC7790, NGC4815, IC1311, NGC2660, NGC2506, Be21, NGC6253, NGC2243, Cr261) and have acquired photometric data for 10 more using various telescopes (Dutch, Danish, and NTT in La Silla; Loiano; TNG). During 1999, we have completed the study of NGC2660 (Sandrelli et al. 1999). In addition, photometric data (on Be29 and Be17) have been acquired at the TNG and high-res spectroscopic data (on NGC4815, NGC2506, NGC6253 and Cr261) at NTT.

1.1.3 Applications to Cosmology

Involved people at OAB: Stanghellini, Tosi.

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 (the only elements produced during the Big Bang, together with H, ^4He and ^7Li) must have been fairly low. This implies that the photon/baryon ratio was fairly high during the Big Bang, a result recently confirmed by the Maxima and Boomerang experiments on the cosmic microwave background. Our group, in collaboration with Steigman (Ohio State Un.), Matteucci (Trieste Un. - SISSA) , Galli and Palla (OAA). colleagues in Arcetri and Trieste, has been particularly active in this field and has been the first in reaching these results (Tosi 2000b).

In 1999, to further study the evolution of ^3He, we have determined (Palla et al. 2000) the $^{12}C/^{13}C$ ratio in a sample of 14 Planetary Nebulae (PNe), 6 of which observed in the ^3He hyperfine transition. By estimating the mass of their progenitors, we have tested the predictions of stellar nucleosynthesis models and found that the majority of PNe have low isotopic ratios, in disagreement with standard stellar models, but in agreement with more recent ones, predicting much deeper mixing during the red giant phase of low mass stars. The implications on the ^3He evolution and on standard Big Bang nucleosynthesis have also been studied (see also Tosi 2000b). Further observations with HST and ESO telescopes are planned to better constrain this crucial issue.

A collaboration has also been set up 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 also applied for a NASA mission (Interstellar

Pathfinder, PI G.Gloeckler) aimed at deriving the local medium abundances of various elements relevant for the Big Bang nucleosynthesis.

1.2 Galactic Globular Clusters

The study of Galactic Globular Clusters has a central role in stellar astrophysics research and *it has been one of the main routes toward significant advances in astronomy in the 20th century* [Baylin (1995, ARAA, 33, 133)].

Indeed, globular star clusters are key-class astrophysical objects since (1) they are prime laboratories for testing stellar evolution; (2) they are "fossils" from the epoch of galaxy formation, and thus important tools for cosmology; (3) they serve as test particles for studying the dynamics of the Galaxy; (4) their individual stars test models for stellar dynamics; (5) they are the largest aggregates in which all post Main Sequence (MS) stars can be individually observed, and thus serve as fiducial templates to study distant stellar systems.

The stellar group at the OAB has been particularly active in this field. It is possible to identify at least three main "pilot" projects which have been developed and are currently carried out at the OAB: 1. Tests of the theoretical stellar models, 2. Dynamics and stellar evolution, and 3. Cosmological applications. A short subsection is dedicated to a new project aimed at the reconstruction of the metal enrichment history of the peculiar globular ω Cen.

1.2.1 Tests of the theoretical stellar models

Involved people at OAB: Ferraro, Fusi Pecci, Messineo, Origlia.

Stellar evolutionary models are often used to derive relevant properties of globular star clusters and galaxies, such as their age and metal content, hence their reliability must be checked. The Luminosity Function (LF) of the stellar sequences in the Color–Magnitude Diagrams (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 specifical

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.

A few years ago, we started an ambitious project aimed to a new global approach to the test of theoretical sequences [in collaboration with B. Paltrinieri (Univ. Roma) and R.T. Rood (Univ. of Virginia)]: the immediate objective of this project was the construction of a *new generation of LFs* based on multi–band (from the near–IR to the far UV) observations for selected Galactic globular clusters (GGCs), in which *all post–MS stars at all radii* have been measured.

The validity of this approach has been shown by our work on M3, for which we have constructed (using photographic and CCD photometry, and HST data) the most complete Color-Magnitude Diagram (CMD) in a Galactic GC, covering the entire cluster from the very center to a radial distance of about 6 arcmin [Ferraro et al. (1993, AJ, 106, 2324), Buonanno et al. (1994, A&A, 290, 69), Ferraro et al. (1997, A&A 320, 757), Ferraro et al. (1997, A&A, 324, 915), Carretta et al. (1998, MNRAS, 298,1005), Laget et al. (1998 A&A 332, 93)]. The global LF for the RGB-SGB-MS region in M3 has been recently published [Rood et al. (1999, ApJ, 523, 752)], showing a substantial agreement of the data with standard theoretical models. Such a data set has been also secured for other clusters with different structural parameters and metallicity (M92, NGC2808, NGC288).

The potential use of such a data-base is huge: the behavior of any evolutionary phase can be studied in the most appropriate photometric band allowing a high resolution analysis of the "fine structure" of each sequence.

The study of the UV sequences (as for example the Horizontal Branch) has been addressed mainly using UV–HST observations. A large data set has been secured during HST Cycle 4-5-6 and the first data analyzed has produced a variety of interesting results [see the invited SAIT review by Ferraro, Paltrinieri & Cacciari (1999), for a complete summary].

The systematic study of the red sequences (Red Giant Branch – RGB–AGB) has been performed using IR and optical data. IR data have been obtained at the ESO–MPI 2.2m telescope using IRAC2, and

a new data set have been secured with SOFI at NTT and ARNICA at TNG. In total we obtained J,K images of a sample of ∼30 GGCs. The RGB main features (colors and LF) for a first sample of 10 GGCs in the IR and 61 in the optical have been published [Ferraro et al. (2000, ApJ, 119, 1282) Ferraro et al. (1999, ApJ, 118, 1738)], showing an excellent overall agreement between the observations and the most updated theoretical models.

We are also analyzing 10 micron ISOCAM observations of 6 massive GGCs in order to study the mass-loss processes along the RGB with varying the cluster metallicity.

1.2.2 Dynamics and stellar evolution

Involved people at OAB: Bellazzini, Cacciari, Ferraro, Fusi Pecci, Messineo.

Many new results are now supporting the claim that dynamical evolution of Galactic Globular Clusters (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 is aimed to use GGCs as a laboratory to study the impact of the (internal) environment and (external) dynamical effects on the evolution of the cluster stellar population. The stellar interactions can deeply affect the dynamical status of the cluster, (1) generating a wide variety of peculiar objects with respect to a normal stellar population and/or (2) producing strong signatures on the LF of canonical sequences.

1. The secured HST observations for this project allowed us to collect a homogeneous data-base for 8 GGCs, 5 more will be observed during cycle 9. The analyzed data in 4 GGCs showed important results: as the discovery of the spectacular population of BSS in M80 [Ferraro et al. (1999, ApJ, 522, 983)], the largest and most concentrated ever found in a GGC. Since M80 is the GGC which has the largest central density among those not yet core-collapsed, this discovery could be the first direct evidence that stellar collisions could indeed be effective in delaying the core collapse. The discovery of UV objects lying in the vicinity of LLGCX sources [Ferraro et al. (2000, ApJ, July 1 issue), Ferraro et al. (2000, in press)], suggests that these stars might be a

new sub-class of cataclysmic variables, produced by stellar interaction in dense core. Similar objects, with strong UV emission have been also found in NGC288 [Bellazzini & Messineo (2000)]; for these candidates VLT-FORS2 spectroscopic follow-up have been obtained. A method for deriving the fraction of binary systems in GGCs from the secondary main sequence in CMD is also under development.

Moreover, deep ROSAT HRI X-ray observations will be used to derive a lower limit to the diffuse X-ray emission of a sample of GGCs. More than 20hr of ROSAT observing time have been allocated to this program. Preliminary results on the detection of a LLGCX in NGC 288 is reported in Sarazin et al. (1999, ApJ, 524, 220) [This research has been carried out in collaboration with R.T. Rood (Univ. Virginia), B. Paltrinieri (Univ. Roma), C. Sarazin (Univ of Virginia)].

2. The LF of stars below the MS Turn Off (TO) is a powerful tool to study the modifications of the Present Mass Function (PMS) in GGCs due to internal dynamical evolution of the cluster and its interaction with the Milky Way. These arguments are very important to derive a reliable Initial Mass Function (IMF) from the observed PMS.

Both (a) the cluster internal dynamics and (b) tidal interactions with the Milky Way significantly contribute to modify the PMF. Our research is now concentrating on finding clear evidences for disk shocking effects on the LF of low mass stars. 24 hours of observing time with VLT-FORS1 have been allocated to this project: 4 GGCs, namely NGC 6218, NGC 6838, NGC 6712 and NGC 6397, have been observed. The result obtained in NGC6712 suggest that this cluster has unambiguous evidence of depletion of low mass stars, due to strong tidal interaction with the Galaxy [Andreuzzi et al. (2000, submitted), Paltrinieri et al. (2000, submitted), Ferraro et al. (2000, submitted)]. [This research has been carried out in collaboration with F. Paresce (ESO), G. De Marchi (STScI), G. Andreuzzi (OAR), B. Paltrinieri (Univ. Roma)]

1.2.3 Cosmological applications

Globular Clusters are the fossils of the remote Galaxy formation epoch, thus they can provide meaningful constrains to a few fundamental

quantities (like for example the primordial helium abundance, the distance scale and, hence, the age scale) of primary cosmological impact. The OAB projects in this field are shortly described in what follows.

- **Distances and ages of Galactic globular clusters via Main Sequence Fitting technique**
  Involved people at OAB: Bragaglia, Clementini, Fusi Pecci.

  The simplest and most robust technique for deriving distances to GCs is the Main Sequence Fitting technique: the comparison of the GC Main Sequence to a suitable "template" formed by the metal-poor subdwarfs in the solar neighborhood, whose distances are accurately measured via trigonometric parallaxes (Sandage 1970, ApJ, 492, 110). Once distances are known, ages follow from the absolute magnitude of the turn-off point (TO) which is the "stellar clock" for dating the clusters.

  Extensively applied in the eighties, the method heavily suffered from the lack of metal-poor subdwarfs with accurate trigonometric parallaxes, implying derived distance moduli accurate to $\pm$0.25mag, and large error bars on ages (15$\pm$4 Gyr, VandenBerg et al 1986, ARA&A, 34, 461). With the release of Hipparcos parallax catalogue, in June 1997, it became possible to build accurate subdwarf template sequences, with metallicities bracketing the CG ones. Moreover, Hipparcos major observational result was that parallaxes for the local subdwarfs are *systematically smaller* (by about 0.2 mag) than ground-based measurements. This directly translated into a "stretching" of the globular cluster distances, and, in turn, in a 2-3 Gyrs decrease of their ages (see Reid 1997, AJ, 114, 161; 1998, AJ, 115, 204; Pont et al. 1998, A&A, 329, 87; Gratton et al. 1997, ApJ, 491, 749). The Hipparcos based MSF method definitely favored the **long distance scale**, and the derivation of **younger ages** for the Galactic GCs comfortably smaller than the age of the Universe.

  In collaboration with Carretta and Gratton (OAP), the study of the distances and ages of the Galactic GCs via MSF based on Hipparcos trigonometric parallaxes has been continued. The MSF distances of a sample of Galactic GCs have been redetermined using an enlarged sample of subdwarfs which includes 95% of the metal-poor subdwarfs in the full Hipparcos catalogue

and whose metallicities have been determined from abundance analysis of high resolution spectroscopic data purposely acquired (Clementini et al. 1999, MNRAS, 302, 22). A careful and comprehensive analysis of the corrections and statistical biases which hamper the MSF distance derivations has been performed and the residual total uncertainty still affecting the Hipparcos based MSF technique has been estimated ($\pm$0.12 mag, to compare with the $\sim$0.25 mag of the pre-Hipparcos analyses). An estimate of the lower limit for the age of the Universe has been derived from the absolute age of the Galactic GCs of 12.9 Gyr, with a residual uncertainty of $\pm$2.9 Gyr [Carretta et al. (2000, ApJ, 533, 215)]. However, there is still a 0.2-0.3 mag difference between the *long* distance scale derived from the MSF and the Cepheids, and the *short* scale, mainly based on statistical parallaxes for RR Lyrae with some support from the Baade Wesselink method. Error bars are still large enough that a final choice between the two scales cannot be made.

Besides parallaxes, a number of different ingredients and assumptions enter into the MSF technique, which all contribute to the final result (i.e. the derived distance moduli), and to its present accuracy ($\pm$0.12 mag). The major contribution to the present MSF uncertainty arises from possible systematic errors (at about 0.1 and 0.02 mag level, respectively) in the reddening and metallicity scale adopted for the field subdwarfs and the GC stars, with errorbars of $\sim$ 0.07 mag from each source. In order to cut the 0.12 mag residual uncertainty still affecting the MSF distances down to $\pm$0.07 mag (again an uncertainty dominated by the parallax error) and the corresponding errors in the GC ages to $\pm$1 Gyr, devoted observations have been proposed for high resolution spectroscopy of globular cluster stars with VLT-UVES [in collaboration with Bonifacio and Molaro (OATS), Carretta, Claudi, Desidera and Gratton (OAPD), Castellani (Univ. Pisa), Chieffi (IAS-CNR), D'Antona (OAR), Francois and Pasquini (ESO), Grundhal (DAO), Sneden (Univ. of Texas), Spite and Spite (Meudon), and Straniero (OA Teramo)]. A total of 12 nights of observing time have been obtained. The first 6 nights allotment is in June 2000 and will be devoted to observations of NGC 6752 and NGC 6397.

- **Distance of GGC using the ZAHB**
  Involved people at OAB: Ferraro, Fusi Pecci, Messineo.

  The large database published in Ferraro et al. (1999, AJ, 118, 1738) has allowed to determine new homogeneous distance moduli for 61 GGCs by adopting the zero-age HB as standard candle. The results indicate that the new distance moduli are in agreement within 0.07 mag with the distance obtained by Carretta et al. (2000) based on Hipparcos, for cluster in the low-metallicity domain. Also that other features in the CMD of GGCs as the RGB-bump and the AGB-bump can be safely used as standard candle. [This research has been carried out in collaboration with M. Limongi (OAR), O. Straniero (OATe), A. Chieffi (CNR, Roma)].

  High quality V and I HST data have been obtained, analyzed and will soon published for M92 one of the most metal poor GGCs and maybe the oldest one. The high photometric accuracy obtained (error < 0.01 mag at the MS Turn Off) will allow us to accurately date this GGCs and set a lower limit to the age of the Galaxy formation epoch. [This research has been carried out in collaboration with R.T. Rood (Univ. of Virginia), R. Buonanno (OAR)].

- **The primordial Helium abundance: a test of the Big-Bang theory**
  Involved people at OAB: Ferraro, Fusi Pecci, Messineo.

  The data-base presented in Ferraro et al. (1999, AJ, 118, 1738) will allow to quantitatively study the population ratios in GGCs to derive a direct estimate of the primordial Helium abundance using the R-method. This will represent a direct check of the Big-Bang explosive genesis of the Universe. [This research has been carried out in collaboration with M. Limongi (OAR) O. Straniero (OATe), A. Chieffi (CNR, Roma)].

1.2.4 The star formation and metal enrichment history of ω Cen.

Involved people at OAB: Bellazzini, Ferraro.

In the framework of a global study of the formation and evolution of the galactic halo, a detailed photometric and spectroscopic study of the stellar population in ω Cen has been recently started [in collaboration with E. Pancino (Univ. BO), G. Piotto (Univ. PD), L. Pasquini (ESO)]. ω Cen is the most luminous and massive GGCs, it is one of the very rare cases of self-enriching GC and it is significantly flattened by internal rotation. Indeed a very peculiar and interesting case of study.

The first data set acquired at the ESO 2.2m with the WFI did show a spectacular and unexpected result: in the $(B, B-i)$ CMD we found for the very first time an anomalous, narrow Red Giant Branch (RGB) significantly redder than the bulk of the normal RGB stars [Pancino et al. (2000, ApJ, 534, L83)], indicating not just a spread in metallicity, that was already known, but the presence of a separate stellar population at higher metallicity. The interpretation is not unambiguous, but may support the accretion event of metal-rich material at a later stage during the formation of the cluster, that may or may not have had the time for dynamical relaxation. Spectroscopic observations of a set of these stars are already secured and will be soon published.

1.3 Globular Clusters Systems

1.3.1 Optical and NIR imaging of Magellanic Cloud clusters.

Involved people at OAB: Ferraro, Origlia.

A wide photometric data–set in the optical and near infrared of a sample of intermediate–age LMC clusters has been assembled [in collaboration with V. Testa (OA Roma) and C. Maraston (Monaco)]. These clusters are the ideal *templates* for studying the evolution of stellar populations in galaxies, with a crucial impact on cosmology.

This data–set would allow (1) to empirically calibrate the epoch of the so–called AGB and RGB *phase–transitions* predicted by the models and (2) to obtain the first quantitative empirical estimate of the AGB and RGB contribution to the total light of a simple stellar population (SSP) with varying its age.

These results will be of fundamental importance for the correct interpretation of integrated colors of high–redshift galaxies.

1.3.2 The Globular Cluster System of the Andromeda galaxy

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

The study of the overall properties of the cluster systems in the galaxies of the Local Group and beyond, and of the stellar populations in nearby galaxies, is important for a complete understanding of the cluster genesis and its connection with the host galaxy formation and evolution.

The OAB M31 team, in collaboration with scientists of the DA and 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 this 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. Several studies are currently being carried on, that are described below.

The M31 cluster system is the largest sample of globular clusters found in the Local Group, sufficiently close to allow individual stellar observations, and negligible affected by reddening, at least for a large sub-set in the outer halo. Moreover, since its intrinsic depth is small compared to the distance (about 0.1 mag in distance modulus), all the degeneracies and problems due to uncertain knowledge of the individual distances can be removed. Since the typical cluster size at the M31 distance is comparable with the seeing disk (10 pc corresponds to 3.3 arcsec), the available existing samples are not yet complete and uncontaminated because the selections made via morphological-visual inspection of candidates fails to select the most compact clusters in the inner areas (mistaken for stars), and the most extended ones in the outer halo (mistaken for background galaxies); moreover, the halo of M31 outside 25 kpc has never been surveyed with deep images taken in sufficiently good seeing conditions and with large-scale plates or CCD-frames. The search and study of globular clusters in the outermost halo are necessary to get a direct estimate of the total mass of M31 (via the Virial Theorem and the Projected Mass Method), hence setting more stringent constraints and yielding fundamental information on its radial distribution.

In this framework (in collaboration with Meusinger (Tautenburg)

and Testa & Corsi (OAR), we are extending the search for globular clusters in M31 up to a distance of more than 50 Kpc from the nucleus; this is done i) by inspecting the UBVR deep plates obtained at the 2m Schmidt telescope in Tautenburg (59 arcs/mm) on a $9 \times 9\,\mathrm{deg}^2$ field centered on M31 with the new projector specifically built to inspect four plates in different colors of the same field simultaneously, in order to get hints on the image structure and color; and ii) by further analyzing the UBVI CCD images of the 9x9 sq.deg. field that will be taken with the 2K-EEV CCD Camera (1 sq. deg. field, 1.5 arcs/pix) mounted on the 91cm Schmidt telescope of Campo Imperatore, in order to obtain magnitudes and colors of all the objects down to U=21, B,V,I=22 or deeper (the peak of the GC LF in M31 being at V=18). The sample of GC candidates obtained by combining the color selection on the CCD data with the morphological analysis on the Tautenburg plates will be finally decontaminated using subsequent spectroscopic observations. This survey will thus allow to detect a significant fraction of faint candidates in the outer regions, that have never been detected so far.

The dependence on metallicity of the HB luminosity is a crucial parameter when deriving relative distances of stellar systems at various metallicities, and can be derived with good accuracy from the analysis of the CM diagrams of globular clusters in external nearby galaxies. Our team is carrying out a long-term project based on observations with HST (FOC+ WFPC + WFPC2) of a wide sample of confirmed GCs in M31 to obtain color-magnitude diagrams from photometry of individual stars. The main goals of the program are: a) to improve the accuracy of globular cluster distance and age determinations, via the accurate determination of the Horizontal Branch luminosity as a function of metallicity for a number of clusters in M31; b) to improve our knowledge of the M31 clusters' stellar populations, basic input for the study of the early evolutionary stages of M31 itself and for the possible use of M31 clusters as templates in population synthesis models; this can be achieved by studying the characteristics of the various parts of the HR diagrams (i.e. HB, RGB and AGB, post-AGB, BSS); and c) to study the cluster surface brightness profiles, in order to get information on the frequency of post-core-collapse vs. King models, and its relation with a number of galactic parameters. CMDs for 10 GCs in M31, reaching at least one magnitude fainter than the Horizontal Branch level, have been already obtained and published; cycle 6 WFPC2 observations (in collaboration with Rich from UCLA and

collaborators) for 10 additional clusters have been recently obtained, providing a statistically significant sample of clusters for a meaningful comparison with our Galaxy. The reduction of the data is in progress, and preliminary results have been presented in an international conference.

It is also under construction a comprehensive, homogeneous revised catalog of all morphological, spectrophotometric, astrometric and kinematic data for the clusters and the clusters candidates in M31.

1.3.3 Globular Cluster Systems in external galaxies

Involved people at OAB: Cacciari, Federici.

It is currently in progress [in collaboration with Held (OAPd) and Testa (OAR)] the spectroscopic study of the globular cluster system of NGC 5128 (Cen A), which is the closest largest elliptical galaxy (distance = 3.5Mpc), and the nearest example of an elliptical galaxy that has recently accreted a late-type satellite, representing so an ideal place where to test current ideas about globular cluster formation. A preliminary analysis, started in 1996 on the basis of spectrophotometric data of a sample of 31 halo gc obtained with MEFOS at the ESO-3.6m telescope showed that the globular clusters of NGC5128 are on average more metal rich than those of our Galaxy, with no super metal-rich cluster. The most intriguing result, however, is the double peak in the metallicity distribution which points to a composite cluster population. In order to give statistical significance to this result and to be able to address the question of a metallicity gradient in the GC system of Cen A, this study has been extended to the inner regions of the galaxy. Spectroscopic observations of a sample of 45 confirmed clusters were taken with EMMI/MOS at NTT in 1998 and the analysis is being carried out.

In the same framework, deep MOS spectroscopy of globular clusters in the Sombrero galaxy (NGC 4594) has been obtained in 1999 using FORS1 at the VLT. NGC 4594 is an early-type spiral with a rich globular cluster system and a dominant bulge; photometric studies suggests the presence of a population of disk clusters more metal-rich than the halo globular clusters. The program aims to verify the existence of cluster sub-populations by estimating their ages and metallicities via measurements of absorption line indices. The cluster kine-

matics will also be employed to probe the mass of the galaxy.

A similar analysis has been undertaken on the elliptical galaxies NGC4125, NGC5831 and NGC6173, whose characteristics suggests them to be the product of recent mergers, and therefore to be good candidates for elliptical galaxies with a population of intermediate-age globular clusters. In order to study the globular clusters around these galaxies and to derive their metallicity distributions using a wide color baseline, deep CCD images were obtained with the TNG/OIG in 1999, and the reductions are in progress.

Spectroscopy of globular cluster systems is essential to investigate the existence of abundance/kinematics subsystems beyond the Local Group, to estimate galaxy masses and to probe dark matter halos, but efficient spectroscopic observations require that a pure sample of bona-fide globular cluster candidates be previously identified. In this scenario, and in preparation for a systematic spectroscopic study at the VLT, we have undertaken a wide-field multicolor imaging of galaxies out to the Virgo cluster distance. Five galaxies of all morphological types have been observed in March 2000 using the Wide Field Imager at the 2.2m ESO telescope; the analysis of these data will lead to the selection by color and shape criteria of large-area catalogs of globular clusters candidates, that will form a database where the deepness of CCD photometry with an area coverage comparable with that of photographic plates are combined.

1.4 Nearby Galaxies

1.4.1 Star formation histories in dwarf irregular galaxies

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

Dwarf irregular 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 local counter-

part of the faint blue galaxies found in excess in deep galaxy counts. Understanding how dwarf irregulars 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 in a number of representative systems of the major morphological sub-classes (blue compact galaxies, dwarf irregulars, giant irregulars) (Tosi 1999). To this aim we are undertaking a long term project (in collaboration with A.Aloisi, M.Clampin, C.Leitherer and A.Nota, at STScI in Baltimore, USA) to study, from deep and accurate photometric data (from ESO VLT and HST), the stellar populations of a number of dwarfs known to show evidence of galactic winds. The resolved stars allow us to derive the epochs and the intensity of the star formation activity and the IMF of these galaxies back to fairly old epochs with the method of synthetic color-magnitude diagrams created by our group (Tosi et al., 1991, AJ 102, 951) and amply tested and applied by the international community.

In 1999 we have completed (Aloisi, Tosi, Greggio 1999) the study of the star formation history of IZw18, based on HST-WFPC2 data, and we are now computing numerical models for its chemical evolution using such results as constraints. We have reduced the NIR data on NGC1569, acquired with HST-Nicmos, and we are completing the analysis of the HST-WFPC2 and HST-Nicmos data on NGC1705. Further HST orbits for optical imaging of NGC1705 have been allocated, but postponed to the end of 2000. The color-magnitude diagrams of these two galaxies will be interpreted in terms of IMF and star formation history in the next few months. Then, numerical chemical evolution models will be computed, taking also into account the effects of the supernovae explosions on the hydrodynamics of their interstellar medium and the possible onset of galactic winds.

In 1999 we have also obtained, in collaboration with E.Tolstoy (ESO) and others, deep images at the ESO-VLT of the Local Group irregulars Aquarius, Cetus and Phoenix (Tolstoy et al., 2000), which will be analyzed with the same way as described above.

1.4.2 Blue Compact Dwarfs

Involved people at OAB: Greggio.

Within the class of dwarf galaxies, the Blue Compact Dwarf (BCD) appear dominated by a recent burst of star formation, which causes

their extremely blue colors. It has been proposed that some of these galaxies (the lowest metallicity ones) there are truly *young* objects, experiencing their very first star formation episode. It has also been proposed that BCDs represent an evolutionary stage of the general class of dwarf galaxies, a stage in which a strong ongoing star formation activity promotes galactic winds which transform a (gas rich) dwarf irregular into a (gas poor) dwarf spheroidal. Finally, BCDs could be the class of objects responsible for the excess faint blue counts described in the previous section. In collaboration with R. Schulte-Ladbeck (Univ. of Pittsburg) and U. Hopp (Univ. of Munich) we are investigating in detail the stellar content of a sample of 5 BCD galaxies for which we have HST photometry proprietary data. By applying the synthetic color-magnitude diagram (CMD) method, we derive the quantitative SF history in these galaxies, which will allow us to properly locate these objects in an evolutionary scenario.

In 1999 we have completed the study of the infrared CMD of VII-IZw403, for which we also had optical HST data. This allowed us to calibrate the infrared magnitude of the tip of the red giant branch as a distance indicator [Schulte-Ladbeck et al. (1999)]. We also studied the infrared CMD of Mrk 178 [Schulte-Ladbeck, Hopp, Greggio and Crone (2000), AJ submitted], and are currently investigating the CMD of the third galaxy in the sample (IZw36). We plan to complete the quantitative analysis of the whole sample within the next two years. We will then be able to address the issue of the mutual relations of BCDs to the other kinds of dwarfs, as well as to derive clues for the interpretation of the evolution of the galaxy population on cosmological time scales.

1.4.3 Dwarf Spheroidal Galaxies

Involved people at OAB: Bellazzini, Ferraro, Fusi Pecci.

Dwarf spheroidal galaxies (dSph) are thought to be the "galactic remnants" of the process of formation of major galaxies. They are the smallest known galactic systems and display the highest mass to light ratios known. Thus, the study of local dSph is of paramount importance to recover the past history of the Milky Way galaxy and for a better understanding of the whole process of evolution and organization of matter in the Universe.

The recently discovered Sgr dSph [Ibata, Gilmore & Irwin (1994)],

in particular promises to be a keystone in the study of Galaxy formation, since (a) it is the nearest galactic satellite, (b) it is the most massive dSph known, (c) it has its own globular cluster system and (d) the process of disruption and final merger with the Milky Way is currently going on, in an advanced stage.

The study of the stellar content and of the globular cluster system of the Sgr dSph has promptly started at the OAB [Montegriffo et al. (1998, MNRAS, 294, 315)] and achieved a major result with the completion of the Sagittarius Dwarf Galaxy Survey [SGDS, Bellazzini, Ferraro & Buonanno (1999a,b)], the widest photometric survey of the Sgr dSph. Three wide ($9 \times 35\ arcmin^2$) fields have been observed with the ESO-NTT, at -2 deg, 0 deg, 2 deg from the center of the galaxy along the major axis and the V,I photometry of 90000 stars has been obtained, to $V \sim 22$. The resulting Color Magnitude Diagrams has been statistically decontaminated by the strong Galactic foreground using the photometry of an additional *control* field and, finally, important constraint on the stellar content, metallicity distribution and star formation history of the Sgr dSph have been derived [see Bellazzini, Ferraro & Buonanno (1999b)].

In the dSph satellite system of the Milky Way there is just another galaxy that can be compared with the Sgr dSph, i.e. the Fornax dSph that has a similar total luminosity and is the only other dSph having a globular cluster system. At odds with Sgr dSph, Fornax has evolved undisturbed, very far (~ 150 Kpc) from the center of the Milky Way. OAB researchers has been involved in the study of this galaxy, and in particular of its globular clusters, since its pioneering phase [Buonanno et al. (1985)]. In the last two years has been completed the photometric study of the globulars and the field of Fornax performed with HST, reaching for the first time the Turn Off point of very old populations in this distant galaxy [see Buonanno et al. (1998, ApJ, 501, 33) and Buonanno et al. (1999)]. The age of all the Fornax globulars was accurately measured for the first time, and the star formation history of the galaxy has been derived.

The most striking result from the above described studies on dSphs is perhaps that, despite the huge differences in size, environment, morphology and star formation history of the parent galaxies, the oldest globular clusters in the Sgr dSph, Fornax dSph, LMC [Testa, Ferraro, Brocato & Castellani (1995, MNRAS, 275, 454] and in the Milky Way *all have the same age and similar heavy element abundance*. This occurrence indicates that some fundamental step in the formation of

galaxies has been simultaneous, at least in the local Universe.

1.4.4 The Andromeda galaxy

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

A wide photometric survey sampling the disc and the halo of the M31 toward 16 different lines of sight has been recently started, using the WFPC2 observations that had the M31 globulars as primary target. A fully automated pipeline has been developed for the data reduction and a final sample of 470704 M31 stars with accurate V,I measures down to $V \sim 27$ has been obtained. The analysis is currently in progress and a first paper is in preparation.

We have also undertaken the study of a peculiar object in M31, identified during a search for globular clusters. This 21st mag. object is possibly extended and is the optical counterpart of a radio and X-ray source. Most likely the object is either a very young, peculiar SNR in M31, or a background AGN, strongly absorbed through the disk of M31. In any case the source is an interesting "test particle" for studying M31 properties. Very high-resolution UBVRI images taken with TNG/OIG in November 1999 show a double-peaked image, with a blue and a red component. Low resolution spectra are necessary to clarify the nature of the object, and are planned for the next available opportunity.

1.5 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. The identification of RR Lyrae stars in composite systems, such as Local Group galaxies, is unambiguous signature of the presence of old, metal-poor stars in these systems. By comparing the properties of RR Lyrae in nearby galaxies with those of the Milky Way variables, the metallicity and age of the oldest population can be estimated.

Being the primary distance indicators in the Galaxy and in the Magellanic Clouds, RR Lyrae stars are corner-stones of cosmological distance and time scales. For instance, the distance to the LMC from

Population II objects is finally founded on the luminosity of the RR Lyrae variables.

The absolute magnitude of the RR Lyrae variables is known to depend on metallicity, but no general consensus has been reached so far both on the correct slope and on the zero-point of the Mv(RR)-[Fe/H] relation. In turn, a dichotomy at a 0.2-0.3 mag level is found to exist between the *short* distance provided by the Baade-Wesselink and Statistical parallax methods applied to field RR Lyraes, and the *long* distance to the LMC as derived from the Main Sequence Fitting of the Globular Clusters and the Population I distance indicators, Cepheids in particular.

Since a very fine tuning of the physical parameters (mass and mass-loss in particular) is required to lead a star evolving along the Red Giant Branch to fall inside the instability strip of the Horizontal Branch, RR Lyraes represent an invaluable test of stellar evolution and pulsation theories. The presence of scatter and large amplitude variations in the light curves are often the signature of double-mode pulsation and Blazhko effect in some of these variables. These phenomena, and the double-mode pulsation in particular, offer a unique opportunity to derive direct informations on the stellar parameters (mass, mass-metallicity relation), structure (magnetic fields, etc.), pulsation mechanism (resonance, mode mixing), as well as on direction and rate of evolution across the Horizontal Branch.

A large number of research programs at various levels of completion are presently carried out, and new projects are proposed to address the RR Lyrae distance scale and the stellar population issues, as well as the impact of the RR Lyraes on stellar evolution and pulsation theories (see sections 1.4.1, 1.4.2, 1.4.3, and 1.4.4 below).

New software tools are being developed, purposely designed to allow the identification of variable stars and to perform period searches and studies of multi periodicities of variable objects.

An effort is also being made to organize the observational material on RR Lyrae variables already in hand or coming from future scheduled observations, in order to made it available in electronic form to the astronomical community (see section 1.4.5).

1.5.1 Distance to the LMC

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

The luminosity, the luminosity-metallicity and mass-metallicity dependence for RR Lyrae variables in the bar of the Large Magellanic Cloud and their role in measuring distances to the LMC are being investigated, in collaboration with Carretta and Gratton (OAPD), Maceroni (OAR), Marconi (OAN) and Castelli (CNR-TS). B and V light curves have been obtained for 128 RR Lyraes and low resolution spectra at minimum light have been obtained for 7 double-mode pulsators in the sample. ΔS metal abundance have been estimated for the 7 RRd's. The average metallicity of the sample is $[Fe/H] = -1.5 \pm 0.2$ dex and the mass metallicity relation they define closely resembles the one followed by the Galactic globular clusters double mode pulsators, thus leaving no room for significant differences in mass between field and cluster variables (Bragaglia et al. 2000, AJ, submitted). The global pulsational properties of the sample as well as a very accurate estimate of the average apparent luminosity of the LMC variables has been obtained from the photometric data : $< V >= 19.325 \pm 0.020$ mag. This value is in very good agreement with the average luminosity of the LMC globular cluster RR Lyraes. An independent estimate of the LMC reddening was obtained from the colors of the edges of instability strip defined by the RR Lyrae in our sample $< E(B-V) >= 0.07$ mag. This value is in perfect agreement with reddening estimates obtained by Cepheids in the same region. These new average apparent luminosity and reddening values allow us to reconcile the **short** and **long** distance moduli of the LMC on a common value of 18.54 ± 0.04 [Clementini et al. (2000, AJ, submitted); Carretta et al. (2000, ApJ, 533, 215); Di Fabrizio et al. (2000, A&A, submitted)]. We have just applied for observing time to measure the metallicities of the entire sample of detected RR Lyraes using the ΔS method. This will allow us to directly determine the slope of the luminosity-metallicity relation for RR Lyrae stars.

1.5.2 Applications of the BW 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, ASP Conf. Ser. Vol 203, 176). This analysis is presently being performed on a group of field RR Lyraes at [Fe/H]=–1.5 in order to derive the zero-point of the absolute luminosity at this metallicity, and derive an accurate estimate of the distance to the LMC, that contains many RR Lyraes for which good quality photometric data are available (Clementini et al. 2000, AJ, submitted). Within this framework, we have started an observing program in the IR (K-band) of a few RR Lyraes in the globular clusters M3 and M92 using ARNICA at the TNG and the IR detector at the AZT24 telescope of Campo Imperatore. Along with accurate radial velocities that are planned to be taken with SARG, this database will be used to apply the B-W method directly on RR Lyraes in these two very interesting globular clusters. 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 that were obtained with smaller telescopes and less powerful detectors.

1.5.3 RR Lyrae in LG galaxies and in globulars

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

A search for RR Lyrae variables in Local Group Galaxies is being carried out [Leo I and other dwarf spheroidals in collaboration with Held, Saviane, Momany and Rizzi (OAPd)] as well as for the variables in the globular clusters of M31. 40 V and 20 B Wide field imager frames of the Leo I galaxy have been obtained with the ESO 2.2m telescope in the nights 22-25/4/2000. Data reduction is in progress. A preliminary search of the M31 GCs variables is taking place on HST observational data already available to us and with the intent to apply for further HST observing time

A reanalysis of the properties of the RR Lyraes in the Sgr globular cluster M54 has been undertaken, using multicolor (BVI) photometric data obtained in 1999. Data reduction and analysis are in progress. The search for RR Lyrae variables in metal-rich globular clusters is being extended to the clusters NGC6304 and Arp2.

1.5.4 Anomalous RR Lyrae

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

The photometric and spectroscopic study of a sample of RR Lyrae variables which exhibit anomalous scatter and large amplitude variation of their light curves is continuing [in collaboration with Carretta and Gratton (OAPd), Ivans and Sneden (Texas Un.), Marconi (OAN), Smith (MSU), and Wilhelm (Southwestern Un.)]. Continuated/adjacent photometric data are being collected with the 1.52m telescope in Loiano, the 60 cm of the Michigan State University and the 40 cm of the Southwestern University, while high resolution spectroscopic data, covering one full pulsation cycle of the variables has been secured with the 2.7 m telescope of the McDonald Observatory. We have already discovered among the stars in our sample a new field double-mode RR Lyrae : CU Comae [Clementini et al. (2000, AJ, in press)]. This is the sixth such RRd identified to date in the field of our Galaxy, and is the most metal-poor ever detected ([Fe/H]=−2.34).

1.5.5 Development of specific software

Involved people at OAB: Clementini, Montegriffo.

We are developing a number of software tools which allow: (i) to achieve the identification of variable objects (VARFIND), (ii) to perform period searches and studies of single and multi-mode periodicities (GRATIS : GRAphycal Analyzer TIme Series) of the variables (this code has proven to be a very efficient and powerful tool during the study of the LMC variables, and in the identification of the double mode pulsation of CU Comae), and (iii) to catalogue and access interactively photometric and radial velocity data as well as periods, epochs, amplitudes, metallicities, ΔS values, etc., and bibliographic references for a large number of RR Lyrae in the Galaxy and in other Local Group systems (VARCAT). A number of facilities are implemented in VARCAT which allow to easily display quantities such as period-metallicity and/or period-amplitude relations, etc. The catalogue is directly interfaced to GRATIS and we plan to keep it updated with the growing body of observational data which are becoming available for RR Lyraes outside the Galaxy, and to make it soon available

on web.

1.6 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 by means of various telescopes: 60 cm and "Cassini" 152 cm of the Bologna Obs. in Loiano and the 600 cm BAT of SAO in Russia, in order to derive their light curves. In addition, the eccentric systems DR Vul, V380 Cyg, RR Lyn, AK Her, ER Vul, BF Aur, which exhibit apsidal motion, are monitored with the 60 cm telescope to obtain precise timings of their light minima.

By means of the "Cassini" telescope - equipped with the Two-heads photometer - the systems XY Leo and RW Com (both of W Uma type) have been observed. With the same telescope (together with the 600 cm 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 collaboration with A. Guarnieri, C. Bartolini, A. Piccioni and G. Cosentino (Astr. Dept. Bologna Un.), G. Beskin (SAO), L. Milano (Napoli Un.) and F. Barone (Salerno Un.)].

1.7 Planetary Nebulae

Involved people at OAB: Stanghellini.

During the past year large progress has been made on the Magellanic Cloud Planetary Nebula (PN) project, a major effort started in 1997 to understand PN evolution in different environments. In collaboration with D. Shaw, C. Blades, M. Mutchler and L. Cawley (STScI), and B. 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.

In Cycle 8 we have observed about 30 LMC PNe (few more are planned) with an innovative method involving slitless STIS/HST spectroscopy, capable of reveal the morphology of LMC PNe[1] in all the major optical recombination and forbidden lines. We obtained the largest sample of extra-galactic 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. The early science results from this study can be summarized as follows:

1. 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 dynamical evolution also depends on morphological type.

2. The LMC PN morphology correlates tightly with the progenitor abundance of the *primordial* elements, i.e., those 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 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 an homogeneous database for LMC PN abundances.

We will also observe in more depth the central stars of the faintest LMC PN nuclei with WFPC2 photometry (20 HST orbits awarded in Cycle 9, PI: R. Shaw). The aim is to correlate PN shapes and central star evolution in a distance-bias free environment.

[1]Note that LMC PNe are spatially resolved only with space astronomy.

Finally, our study will be extended to SMC PNe (55 HST orbits awarded in Cycle 9, PI: L. Stanghellini) 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.

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 an homogeneous sample for testing the evolutionary implications of metallicity variations in stellar evolution.

1.7.1 Morphology of Galactic Planetary Nebulae

In 1996, 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 from this investigation [performed in collaboration with Villaver, Guerrero and Manchado (IAC)] can be summarized as follows:

1. 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 by using it 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 about 7 kpc.

2. The distribution of PN nuclei on the logL-logT plane has been analyzed, and the results of Stanghellini et al. (1993, A&A 279, 521) has 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 planetary nebulae with the morphology of the hosts.

1.7.2 Post-Asymptotic Giant Branch Evolution

A long-lasting initiative has been undertaken [in collaboration with A. Renzini (ESO)] with the aim of producing synthetic post-AGB evolutionary tracks to study the effects of theoretical assumptions on observable diagrams (e.g., HR diagram, Mv-age diagram, mass distribution, luminosity function, etc.). By means of the Montecarlo procedure, we explore the parameter space of the assumptions on the evolutionary and population models by studying the effects of the Initial Mass Function (IMF), the Initial Mass-Final Mass Relation, the transition time from the AGB to the PN phases, the amount of envelope mass at the end of the envelope ejection, the planetary nebula lifetime, and the hydrogen- and helium-burning phases of the central stars.

A first important result is that the key element for post-AGB evolution is the envelope mass at the superwind[2] quenching [Stanghellini & Renzini (2000)]. Such parameter does not afford physical prediction, and this may be the very reason why the comparison between models and data in the realm of the post-AGB populations have been so unsatisfactory to date (see, for example, the criticism to the results from the use of the planetary nebula luminosity function as a secondary distance scale indicator).

Our post-AGB population synthesis code could be used in the future for a full host of different applications. In particular, we foresee its application to check the invariance of the planetary nebula luminosity function for different luminosity cut-offs, IMFs, SFRs, and population metallicity.

1.8 Pulsars

Involved people at OAB: D'Amico, Possenti.

[2]The superwind is the massive, slow wind at the end of the AGB, peeling the AGB star of most of its envelope, and forming the planetary nebula.

1.8.1 Parkes Multibeam Pulsar Survey

In the last two years we have been involved in a major survey of the Galactic plane for pulsars using the Parkes radiotelescope in NSW (Australia). This project is the result of a collaboration between the Australia Telescope National Facility, the Jodrell Bank Observatory, the Massachussets Institute of Technology and the Bologna Astronomical Observatory. The survey uses the new 1.4 GHz multibeam receiver and a large filter-bank system. The survey proved already to be very successful in the discovery of distant pulsars. So far, more than 500 new pulsars were discovered, including about 15 young pulsars, two radio pulsars with very high magnetic field, and several new interesting binary systems. [Camilo et al. (2000), D'Amico et al. (2000), Manchester et al. (2000)].

1.8.2 Search of the Globular Cluster system for millisecond pulsars

Globular Clusters were proved to be rich in millisecond pulsar. About 50 % of the millisecond pulsars is contained in Globular Clusters. The discovery of additional milliseconds in Globular Clusters might represents a useful tool in the understanding of the Cluster dynamics, of the evolution of binary systems, and might ultimately provide a new sample of interesting and exotic objects. A proposal for a new systematic search of the Globular Cluster System for millisecond pulsar using the Parkes radiotelescope has been approved in 1999. In this search, deep integrations were performed in order to achieve a high sensitivity level, in the need to process huge (typically 8 GB) data set for each target. We have developed a new efficient parallel computing system using a network of workstation at the Bologna Astronomical Observatory.

1.8.3 Millisecond Pulsars Survey at the Northern Cross

A large scale survey for millisecond pulsars at 408 MHz has been undertaken, using the Italian Northern Cross radiotelescope near Bologna. So far, about 30% of the sky $\delta > 0$ was observed, resulting in the detection of 35 known pulsar, 5 known millisecond pulsar and one new millisecond pulsar, having a period of 4.86 ms and a very low DM = 4.3 $cm^{-3}pc$. This new millisecond pulsar was then observed at Parkes in order to measure the dynamic spectrum at low frequency and derive

a scintillation velocity, which resulted in the observation of a velocity of the order of 10 km/s (Nicastro el al., in preparation).

1.9 Integrated Light of Early Type Systems

Involved people at OAB: Greggio.

1.9.1 Elliptical Galaxies

Elliptical galaxies are a cornerstone in our understanding of the galaxy formation process in a cosmological frame. According to the currently most popular models, elliptical galaxies are the outcome of (multiple) merging of already formed units, as a natural result of the hierarchical models which successfully account for the large scale structure observed in the local universe. The hierarchical models, however, give strong predictions for the clustering of the dark matter, while the behavior of the luminous matter depends on many parameters, which are less constrained. Of particular importance is to establish if the most massive ellipticals are young or old, so as to derive the epoch of the major episode of star formation. Unfortunately, the vast majority of ellipticals cannot be resolved into single stars, and the age-dating of their stellar content relies on studies of the their integrated light. These studies are severely hampered by the age-metallicity degeneracy, i.e. the same colors and spectral indices are obtained when decreasing the age and increasing the metallicity at the same time. In principle the degeneracy can be broken on index-index plots, where the two indices have different dependences on age and metallicity. In practice, this procedure needs accurate and well calibrated models of the integrated light from stellar populations. In collaboration with C. Maraston (Univ. of Munich) we are testing the sensitivity of the model spectral indices to the input parameters which enter their computations, exploring both physical and numerical uncertainties.

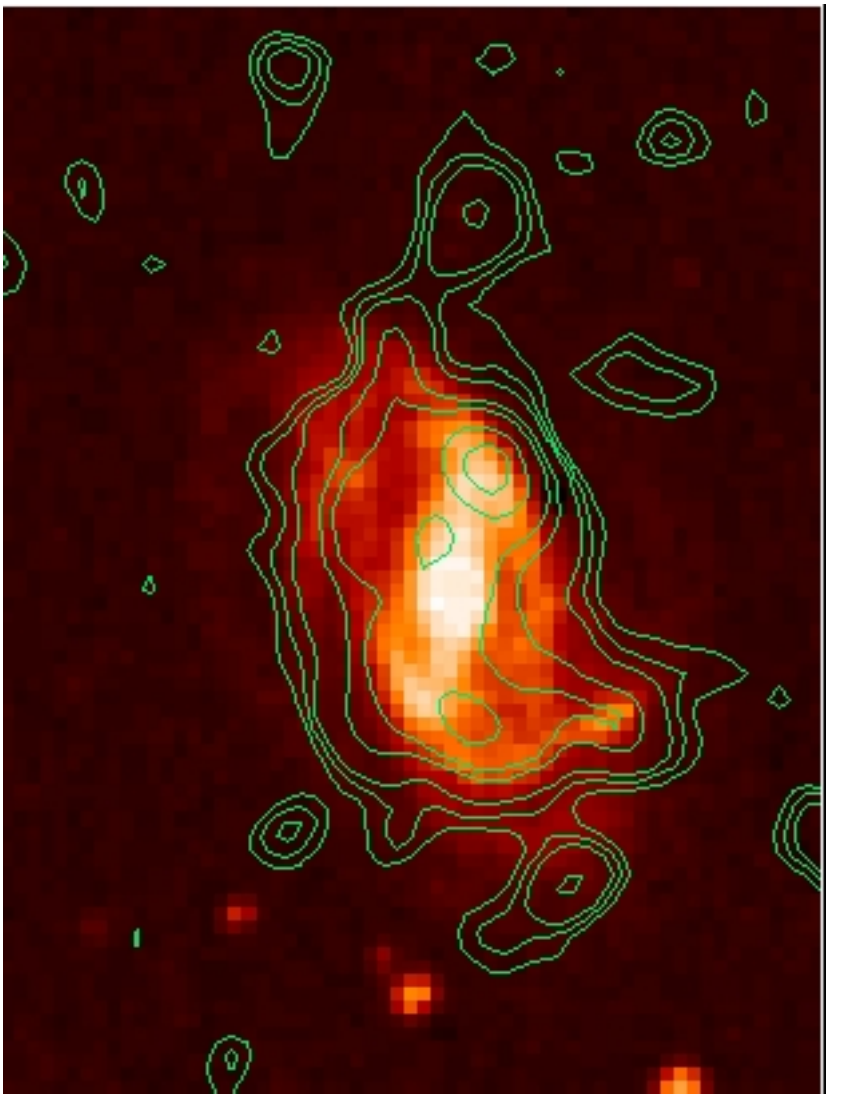
In 1999 we updated the code for the computation of the evolution of integrated light of single age, and single metallicity populations of single stars, to predict the evolution of the whole spectral energy distribution. We applied this instrument to interpretate the evolution with redshift of color gradients in ellipticals, comparing the model predictions to data for nearby galaxies and for galaxies at redshift $\approx$ 0.4 [HST proprietary data; Saglia et al. (2000)].

We also acquired ESO, 1.5m spectra of globular clusters in the Galactic Bulge. These data will be soon reduced and compared to the models predictions, to achieve a proper calibration in the high metallicity range, which is a relatively poorly explored regime. This work is done in collaboration with A. Renzini (ESO), C. Maraston, R. Saglia and T. Putzia (Univ. of Muenchen).

1.9.2 Dwarf Elliptical Galaxies

In the general class of early type galaxies, the nature of the dwarf ellipticals/dwarf spheroidal galaxies is puzzling: is there an evolutionary link between them and dwarf irregulars, or do they evolve along an own path, strongly influenced by interactions with other more massive galaxies? Few data currently exist for this class of objects. In collaboration with R. Bender, U. Hopp and D. Thomas (Univ. of Munich) we have obtained spectra of 10 dE in the Virgo Cluster at the Calar Alto 3.5m telescope. These data will be analyzed to derive the kinematical structure and the properties of the stellar populations in these galaxies. In particular, we will adress the question of their chemical properties: do they share the α-elements overabundance observed in luminous ellipticals? Are they consistent with chemical evolution models of disks undergoing tidal stripping, or galactic winds? The comparison of the chemical properties of dwarf spheroidals with those of other galaxy types will allow us better locate this class of objects in the general classification scheme.

2 Extragalactic Astronomy and Cosmology



ISO (15 micron) contours of a spiral galaxy in the ELAIS region S2 overimposed to the optical Digitized Sky Survey (DSS) image (see section 2.3.6)

Involved people at OAB:

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

- *Fellows:* F. Fraternali, C. Gruppioni, M. Murgia, F. Pozzi, C. Vignali.

Observational extra-galactic 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, the physical properties of active galactic nuclei (AGNs) to observational cosmology. Very characteristic is 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, 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 (e.g. X-ray satellites like ROSAT and BeppoSAX, the VLT).

2.1 Structure and evolution of galaxies

The structure of galaxies has been 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

Involved people at OAB: Ciotti, D'Ercole, Londrillo.

In collaboration with G. Bertin (SNS-Pisa) Ciotti has clarified, using an analytical approach, some properties of the surface brightness profiles commonly used in observational works for the modeling of elliptical galaxies. The obtained simple relations (derived by using asymptotic expansion technique applied to the exact formulae of little use in practical applications) are of great utility both for the interpretation of real data and their modeling.

The Abel inversion has been generalized from spherical to toroidal symmetry. Such a generalization allows one to expand a generic density distribution, axially symmetric in a pseudo-basis of toroidal components. The obvious application of the developed technique is the reconstruction of the density distribution in S0 galaxies or astrophysical disks (planetary, galactic, and so on) from the observed (projected) density distribution.

On the subject of galaxy dynamics, generalized the study of the dynamical constraints on the distribution and amount of dark matter in the central regions of elliptical galaxies and bulges has been extended and generalized. This investigation is carried out by using analytical methods developed by Ciotti in the past years. The results obtained can be used in many applications, e.g., in the assignment of the initial conditions for multi-component N-body simulations or in the construction of realistic (self-consistent) models to be used in the modeling of observations. For example, in collaboration with Londrillo (who for this purpose developed a parallel particle-mesh numerical code) they are investigating the stability of elliptical galaxies in the presence of dark matter halos.

Another collaboration of Ciotti with G. Bertin and Londrillo concerns the construction of a family of phase-space distribution functions, obtained by a tailored flattening of truncated, anisotropic polytropes. The explicit form of these functions is very simple. The associated density profiles (obtained by solving numerically, with a numerical code developed by Londrillo, the associated non-linear Poisson equation) are of considerable interest, reproducing in a physically sound framework the main properties of complex dynamical systems like the so-called "peanut-shaped" bulges.

Ciotti, D'Ercole and S. Recchi (University of Trieste), completed a study about the effects of tidal interactions on the hot X-ray ISM of elliptical galaxies. This study has been done adopting a 2D hydro code developed by D'Ercole. In particular, it revealed the formation of cold filaments of a few kpc embedded in the X-ray halo. In some ellipticals such filaments are indeed observed.

In collaboration with J.P. Ostriker (Princeton University) Ciotti has developed an evolutive scenario which links the X-ray evolution of elliptical galaxies with QSO evolution and activity. They propose a solution of a puzzling question: according to them 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 explored in great detail by using a specific numerical hydrocode which takes into account several aspects of radiative transfer.

Other research projects were started by our group in 1999 and should be completed in 2000: a detailed investigation of the physical origin of the fundamental plane of elliptical galaxies, the study of the dynamics of dark matter halos in elliptical galaxies, the numerical simulation of X-ray halos of elliptical galaxies, the study of resonance phenomena between stellar orbits in galaxies and the cluster tidal field, the interaction of the globular cluster system and the density profile of the parent galaxy, the extension of the applicability range of the feedback modulated accretion solutions on black holes.

In 1999 D'Ercole studied the ISM of elliptical galaxies. He also studied the ISM evolution in starburst galaxies. In collaboration with Brighenti (University of Bologna) they performed 2D simulations, taking into account galactic rotation and thermal conduction, in order to describe the circulation of metals ejected by SNsII in such systems. The models show that metals are partially lost by the galactic wind powered by SNsII, while the condition for a second star formation burst are created again after 1 Gyr from the previous burst.

In collaboration with F. Matteucci e S. Recchi (University of Trieste), D'Ercole also made numerical hydrodynamical models which take into account the chemical evolution in starburst galaxies. through the implementation of a code used for one-zone chemical models. In these models the activity of SNsI and SNsII is considered.

In collaboration with S. Pellegrini (University of Bologna) D'Ercole and Ciotti, they are performing a number of numerical 2D simulations to study the effect of the merging with a dwarf galaxy on the X-ray emission of the target elliptical galaxy.

2.1.2 Neutral hydrogen studies

Involved people at OAB: Sancisi and Fraternali.

Sancisi is continuing a number of neutral hydrogen studies, which he initiated while still at the University of Groningen.

The recent 21-cm line study of NGC 891 by Swaters, Sancisi and

Van der Hulst (ApJ 491,140, 1997) has shown the presence of an extended HI halo which seems to rotate more slowly than the disk. Schaap, Sancisi and Swaters (Astron. Astrophys. 356, L49, 2000) have just completed a similar study of the vertical distribution and the kinematics of HI in the spiral galaxy NGC 2403 and have reached for this galaxy conclusions similar to those obtained for NGC 891. They have used 21-cm line observations with the Westerbork Synthesis Radio Telescope and have discovered a remarkably asymmetric structure, a tail towards the systemic velocity -the 'beard'- in the 21-cm line profiles. They have interpreted this as evidence for the presence of gas in the halo of NGC 2403. The 3-D models indicate that this gas has a somewhat lower (about 25 km/s) rotational velocity than the gas in the plane. A vertical gradient in the rotational velocity may mean a gradient in the gravitational potential and serve, therefore, to investigate the vertical distribution of dark matter.

As a follow-up of this study, new observations of NGC 2403 with higher sensitivity and resolution have been obtained with the VLA by Sancisi, Oosterloo and van Moorsel. A PhD student at the Bologna Astronomy department, Filippo Fraternali, has joined the team for the data reduction and in particular for the model analysis of the 3-D density distribution and kinematics. The preliminary results confirm the conclusions of Schaap et al. regarding the presence of a slowly rotating HI halo around NGC 2403. In addition, these new VLA data also indicate that the halo HI has radial motions (probably an overall inflow of order 25 km/s) and other peculiar high vertical motions as well. These striking new results present a real puzzle as to the origin of the halo gas: a galactic fountain or infall of primeval intergalactic gas?

Swaters, Sancisi, Van Albada and Van der Hulst have studied the dark matter content of about 80 late-type dwarf galaxies which are part of the WHISP sample (see PhD thesis of Swaters, Groningen University, 1999). High quality HI rotation curves have been derived for a subsample of 40 objects. The derived rotation curves are found to be more steeply rising than hitherto found for dwarf galaxies. Mass modeling indicates that these dwarf galaxies do not need large amounts of dark matter in the inner parts. At larger radii dark matter is still needed to explain the shape of the rotation curves.

Swaters, Schoenmakers, Sancisi and Van Albada (MNRAS 304, 330, 1999) have studied the kinematical lopsidedness of spiral galaxies. They have pointed out the frequency of occurrence of the phe-

nomenon and discussed the possible relationship with asymmetries in the potential.

M. Kregel (Kapteyn Institute, Groningen) and Sancisi have completed their study of the HI structure and kinematics of the peculiar starburst galaxy NGC 3310 (UGC 5786). The optical image of this galaxy (see Arp 217) is dominated in the outer parts by the so-called 'bow-and-arrow' structure. Kregel and Sancisi have found new evidence bearing on the origin of the starburst. The main bulk of the HI coincides with the bright optical disk and shows differential rotation like in normal spiral galaxies. But its velocity dispersion is unusually large (20 km/s) for a spiral galaxy, indicating that the disk is highly perturbed. There are, in addition, two prominent HI tails, one extending to the north-west and the other to the south. The newly found HI structures and perturbed kinematics and the already known optical peculiarities strongly suggest a recent major merger between two gas-rich galaxies. NGC 3310 may be the example of a major merger in which most of the gas in the inner parts has been preserved in neutral atomic form and either one of the progenitor disks has survived or a new disk has formed.

Balcells (I.A.C., Tenerife), Van Gorkom (Columbia University) and Sancisi have studied the gas distribution and kinematics in the recent merger NGC 3656, a perturbed elliptical galaxy. They have followed up with new 21-cm observations with the VLA an earlier HI study with the WSRT by Balcells and Sancisi (AJ. 111, 1053, 1996). The earlier detection of HI is confirmed and the new, higher sensitivity observations have revealed a wealth of new features in the HI distribution. In the inner parts the HI coincides with the dust lane and shows rapid rotation like a warped disk seen edge-on. Further out, it follows the prominent optical shell-like structure to the south. In addition, the new data reveal extended HI tails in the outer parts and the presence of nearby HI-rich companions supporting the earlier suggestion of a possible galaxy merger.

NGC 3656 is a useful laboratory to study the evolution of neutral gas in early-type galaxies. NGC 3656 is reminiscent of Cen-A for its warped HI configuration in the inner parts. The presence, however, of a prominent optical-HI shell, or disrupted satellite, to the south suggests that NGC 3656 is in an accretion state earlier than that of Cen-A.

2.2 Active galactic nuclei

2.2.1 Optical studies

Involved people at OAB: Stirpe, de Ruiter, Zitelli.

In collaboration with A. Robinson and D. Axon the studies on the statistics of broad emission lines in AGN have been continued. In particular, work has started on analyzing the spectra of the H-Beta region, which involves a complex series of de-blending and fitting operations. They are attempting to automate the process by writing an interactive program in the IDL language.

Stirpe and de Ruiter are involved in long term monitoring programs to study the variability of emission lines and continuum in Seyfert galaxies. Stirpe has participated in the International AGN Watch monitoring of the Narrow Line Seyfert 1 galaxy Akn 564, which was the target of an RXTE campaign in 1999. The Loiano 1.5m telescope provided differential photometry for the parallel ground-based campaign, detecting continuum variations of about 5%.

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 almost 15 years of observations. The data are expected to be submitted for publication by the middle of 2000.

In collaboration with P. Focardi, B.Kelm (University of Bologna) and T.Venturi (Institute of Radio Astronomy CNR, Bologna) Zitelli is studying the relationship between nuclear activity and environment for active galactic nuclei. There is strong evidence that the environments of Active Galactic Nuclei are complex, in the local universe but also up to $z \sim 3$. Although it is well established 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. The complexity of the discussion increases because the samples used are limited in number. To improve the statistical uncertainty a strategy was adopted based on statistically significant samples of nearby AGNs and an appropriate control sample, selected on the basis of criteria that are independent of morphology and environmental properties. The global properties of active galactic nuclei are compared with those of a sample of "normal"galaxies, in particular the excess of perturbed Seyferts in small

systems with respect to normal galaxies. This study, started one year ago, is still in progress.

2.2.2 Near-IR studies

Involved people at OAB: Origlia.

In collaboration with E. Oliva (OAA) and A. Moorwood (ESO) Origlia is performing near IR spectroscopic surveys of active galaxies to classify their starburst events and to trace their evolution also in connection with the nuclear activity. A few interesting absorption features due to the red stellar populations and emission lines from the ionizing gas are indeed present in the infrared spectra of starburst and Seyfert galaxies. By measuring the line velocity dispersions and equivalent widths, an estimate of the stellar light to mass ratios and warm dust emission can be inferred. These quantities provide important constraints to the starburst–AGN connection in the galaxy central regions.

2.2.3 X-ray studies

Involved people at OAB: Comastri, Vignali.

Several observational programs aimed to understand the high energy emission properties of different classes of AGN are carried out using data from ROSAT ASCA and BeppoSAX X–ray satellites.

The X–ray properties of high redshift radio–quiet have been investigated in some detail using ASCA. Relatively good quality X–ray spectra have been obtained for about a dozen of quasars in the redshift range 1.8–2.5. The first results (concerning only 5 objects in the sample) clearly indicate the lack of intrinsic absorption and of the characteristic reprocessing features (Compton hump and iron line) which are common among lower luminosity Seyfert 1 objects. In addition the average X–ray spectrum (extending up to 30 keV in the quasar frame) is significantly flatter than that of lower redshift quasars. Unfortunately the present data do not allow to distinguish between a redshift or a luminosity dependence. Further insights are expected from the analysis of the entire sample and from the comparison with literature data (currently in progress).

The BeppoSAX Core Program observations of a sample of *Narrow Line Seyfert 1 Galaxies* (NLS1) in the 0.1–10 keV band were recently completed. The capabilities of the BeppoSAX detectors, and especially the relatively large MECS effective area at high energy (> 5 keV), have been fully exploited to further investigate, with respect to previous ROSAT and ASCA observations, several of the distinctive properties of NLS1. More specifically, the main scientific objective was to test whether the 2–10 keV spectral indices distribution and the properties of the iron K–shell features in the 6–10 keV region were different from that of normal, broad–line Seyfert 1 and how the peculiar X–ray properties of NLS1 (steep X–ray spectra and rapid variability) are linked to the optical ones (narrow Balmer lines and strong Fe II emission). The most important results were the discovery, in a few objects, of spectral features due to highly ionized matter (iron line and edge) and the parameterization of the overall X–ray continuum in terms of a strong soft excess, best fitted with a thermal black–body like spectrum, plus a steep power law component. The program was complemented by several quasi-simultaneous optical and UV observations which allowed to perform broad band spectral fits with accretion disk models. The results favor a low mass highly accreting black hole.

AGN synthesis models for the X–ray background are also investigated. Even though there is a relatively good agreement with the present observational data a coherent self–consistent picture has yet to be reached. The major problem is the discrepancy between the predictions of those models computed assuming the most up–to–date results, and the high energy (> 2 keV) source counts. In particular the lack of highly obscured high luminosity objects (the so–called type 2 quasars) is difficult to explain. One obvious possibility is a substantial contribution from non–AGN, flat spectrum sources. Another interesting possibility is that the optical properties of X–ray obscured AGN are different from what expected (i.e. narrow lined AGN). The large variety in the optical classification of faint X–ray obscured HELLAS and Chandra sources would support the second hypothesis. As soon as sizeable samples of X–ray selected sources will be available thanks to the foreseen medium–deep and deep Chandra and XMM–Newton surveys it will be possible to better constrain the AGN models parameter space.

2.2.4 Radio galaxies

Involved people at OAB: de Ruiter, Murgia.

De Ruiter is involved in various projects aimed at studying the physical properties of radio galaxies.

It has now been established that also radio jets in low luminosity radio galaxies (Fanaroff-Riley type 1) are relativistically beamed close to the nucleus, but quickly decelerate (in contrast with high luminosity radio galaxies) to become, after a few kpc, non-relativistic, mildly supersonic outflows. A statistical study of B2 radio galaxies by Laing, ..., de Ruiter, et al. (1999, MNRAS, 306, 513) shows that the small scale brightness asymmetries are in complete agreement with this picture.

Murgia et al. studied the radiative ages of low luminosity radio galaxies by interpreting spectral steepening as being due to the aging of synchrotron emitting electrons. Although the subject of synchrotron aging remains controversial, a coherent picture emerges, in which radio source regions with different radio spectral indices can be interpreted as representing different phases in the life of a radio source (Murgia, ..., de Ruiter, et al 1999, A&A, 344, 7).

With the Hubble Space Telescope snapshot images in V and I were obtained (so far) for about 60 % of the B2 sample of low luminosity radio galaxies. An article presenting these images has been submitted to A&A (Capetti (Observatory of Torino), de Ruiter, et al. 2000). Almost two thirds of the galaxies show dust features, very often in the form of dust bands or circumnuclear disks, and further study will reveal if there is any relation between the properties of the radio source and the dust.

2.3 Surveys and Observational Cosmology

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

2.3.1 VIRMOS

Involved people at OAB: Bardelli, Cappi, Origlia, Pozzetti, Zamorani, Zucca.

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

The visual spectrograph will be shipped to Chile in summer 2000 and after a few months of commissioning and testing will be operational at the beginning of 2001. A couple of years later also the infrared spectrograph will be operational.

The huge multiplex capabilities of the two spectrographs 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 shallow survey (16 sq.deg.) and about 50,000 galaxies from the deep survey (1 sq.deg.) and the expected redshift coverage (up to $z \sim 2$, 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. Some of the crucial issues which will therefore be possible to address from these data are: a) detailed test of the predictions of various models of galaxy evolution (e.g. hierarchical versus monolithic models); b) precise estimate, on the basis of a single sample with well understood selection criteria, of the star formation history up to at least $z \sim 2$; c) study 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 ~ 1000 AGNs 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.

This survey, which will start in 2001, has already required a lot

of scientific preparation. Significant contributions were made to the following issues:

a) definition of the main scientific goals and of the observing strategy;

b) participation to the time requests to ESO for obtaining the needed photometric data in the U and K bands;

c) definition of the data management and implementation of the survey database;

d) development of software for the scientific data analysis.

2.3.2 K20 Redshift Survey

Involved people at OAB: Mignoli, Pozzetti, Zamorani.

Bologna Observatory participates, with the observatories of Arcetri, ESO and Rome, to an ESO VLT Large Program (PI A. Cimatti (Arcetri)), which has started in 1999. This program (called K20; link *http://www.arcetri.astro.it/∼k20/*) 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 field (taken from the public ESO EIS data) 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 makes use of both optical and near-IR spectroscopy. The main scientific goal is to compare the observed redshift distribution with the predictions of the galaxy formation models in order to obtain stringent clues on the formation and evolution of the present-day massive galaxies. The main byproducts are: the K-band luminosity function, 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 made in 1999 provided spectra of all galaxies down to a completeness level of about $K < 19.3$, and the spectral analysis and the redshift measurements are in progress.

2.3.3 The ESO slice project

Involved people at OAB: Cappi, Merighi, Mignoli, Stirpe, Zamorani, Zucca.

The ESO Slice Project (ESP) is a galaxy redshift survey performed at the ESO 3.6m telescope, which produced a complete sample of $\sim$ 3500 galaxy spectra with $b_J \leq 19.4$ over an area of $\sim$ 25 square degrees: the project (P.I. G.Vettolani) is the result of an international collaboration in which the Bologna Observatory is deeply involved Mignoli, Stirpe, Zamorani, Zucca). It is worth recalling the following results, obtained from the ESP survey:

– The shape and the normalization of the field galaxy luminosity function were determined over an unbiased volume of the Universe, finding an excess of faint galaxies.

– Almost half of the ESP galaxies present spectra with emission lines, which allowed the analysis of star formation properties in the local Universe.

– The spatial analysis of the ESP galaxies provided information about the topology of the Universe, excluding the hypothesis of a fractal distribution, and about its clustering properties. Moreover, a large underdense region was found for distances < 140 h^{-1} Mpc.

– Clustering properties were analyzed in detail, measuring both the correlation function and the power spectrum of the ESP galaxy distribution. These estimators were derived with various methods and compared with the literature results obtained for brighter galaxies.

– Groups of galaxies in the ESP survey were objectively identified above a fixed overdensity threshold and their dynamical properties were studied in detail. Moreover, spectral properties of galaxies in groups were compared with those of field galaxies, finding a gradual decrease of the fraction of emission line galaxies among members of systems of increasing richness. This result confirms that the morphology–density relation found for clusters also extends toward systems of lower density.

These results are presented in a series of papers already published (the ESP team (1997) A&A 325, 954; (1997) A&A 326, 477; (1998) A&ASS 130, 323; (1998) A&A 336, 445; (1998) A&A 334, 404; (1999) A&A 342, 1; (2000) A&A 355, 1); other papers are now in press or submitted.

Further information about ESP can be found at the page
http://boas5.bo.astro.it/∼cappi/esokp.html.

2.3.4 Bright galaxies from WENSS

Involved people at OAB: de Ruiter, Stirpe.

The Westerbork Northern Sky Survey has mapped the sky (above declination $+30^{o}$) at 325 MHz (and is complementary to the NVSS survey at 20 cm made by the VLA). The overall catalogue contains about 200000 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 automatic procedures used in the extraction process have now been tested, and a final list of WENSS bright galaxies will be available before the end of 2000. A first analysis, based on a small area (the WENSS minisurvey), was given in de Ruiter, ..., Stirpe, et al. (1998, A&A, 339, 34).

2.3.5 The HELLAS Survey

Involved people at OAB: Comastri, Ciliegi, Mignoli, Vignali.

Bologna Observatory collaborates with the observatories of Arcetri (R. Maiolino), Rome (F. Fiore), the Third University of Rome (G. Matt, F. La Franca) and with C. Vignali (University of Bologna) in the analysis of a large sample of hard X-ray selected sources discovered by BeppoSAX in the 5–10 keV energy range. The survey (dubbed "High Energy Llarge Area Survey", HELLAS) has now been completed. The final sample consist of 147 sources detected down to a flux limit of 5 $\times 10^{-14}$erg cm^{-2} s^{-1} where about 20–30 % of the hard X–ray background is resolved. A sizeable fraction of the HELLAS sources are characterized by hard spectra, as can be judged from the hardness ratio X–ray analysis, suggesting the presence of intrinsic absorption. The number counts and absorption distribution are in substantial agreement with AGN synthesis model predictions (Comastri et al. 1999). In order to better understand the nature of the hard X–ray sources several multiwavelength (radio, sub–mm, optical and near infrared) follow–up programs have been or are being carried out.

The most interesting observational results indicate that the optical and X–ray properties of X–ray obscured AGN are different from what expected (i.e. narrow line type–2 AGN). Even though the presence of an obscured AGN is well established by X–ray observations, the

optical morphology, brightness profiles and photometric colors in various bands are similar to those of non-active galaxies (Vignali et al. 2000; Maiolino et al. 2000). Moreover the optical counterparts of a few hard absorbed sources have been identified with broad–line "blue" quasars. As a result the hard X-ray population contributing to the XRB appears to be characterized by a wider range of X-ray and optical properties than previously thought, and that other parameters, besides the nuclear absorption, are required for a complete description of its properties. The Chandra discovery of faint hard X–ray sources associated with optically faint and non-active galaxies (Mushotzky et al. 2000) has confirmed and extended the scenario above described.

A 5 GHz survey has been obtained for the HELLAS sources with declination lower than -40 deg in June 1999 using the Australia Telescope Compact Array (ATCA). The results obtained with the ATCA observations show that a very high fraction of the HELLAS sources show radio emission (8 of the 20 HELLAS sources have a radio counterpart). Vice-versa, radio follow-up of soft (0.5-2 keV) X-ray selected samples has shown different percentages of radio/X-ray associations (about 10 per cents). In order to check if this high percentage of radio/X-ray associations will be confirmed also for large sample of hard X-ray sources and for very faint sources selected with the Chandra and XMM satellite, VLA radio observations of about 100 HELLAS sources northern than DEC -40 deg and radio (with ATCA) follow-up of two Chandra deep fields will be carried out during the year 2000. If the nature of the hard X-ray selected sources is really different from that of soft X-ray selected AGN (as supposed by different authors), the radio observations will provide a useful tool to better understand the nature of these objects and than to solve the hard X-ray background problem.

2.3.6 The ELAIS Survey

Involved people at OAB: Ciliegi, Gruppioni, Mignoli, Pozzi.

ELAIS was the largest non serendipitous ISO field survey, utilizing 377 hours of the Open-Time programme. Ciliegi and Mignoli. The project is a collaboration venture between 26 institutes from 11 countries. The survey covers around 13 sq.degree with observations in four bands covering much of the ISO wavelength window (6.7, 15, 90 and 175 micron) using both ISO-CAM and ISO-PHOT. During

1999, in collaboration with Francesca Pozzi (PhD student, University of Bologna) and Carlo Lari (Institute of Radio astronomy CNR, Bologna) the data reduction of the ISO-CAM data at 15 micron in a region of the sky of 2 × 2 degree called S1 has been performed. They used the data reduction software developed by Carlo Lari, which was especially designed to overcome the main problems affecting ISOCAM LW data and to detect faint sources. With this new reduction technique a complete sample of more than four hundred 15μm sources brighter than $\sim$1 mJy has been obtained.

An extensive follow-up programme is begin undertaken in the ELAIS regions, utilizing a vast battery of telescopes around the world and also a number of satellites. Radio observations at 20 cm using the VLA and ATCA radio telescopes have been obtained. The aim of these observations were to study the well know radio-infrared correlation established for the IRAS sources to radio and infrared fluxes never reached before. The radio catalogues obtained from these observation have been published in two papers on the MNRAS. Moreover in collaboration with F. La Franca (University of Rome) and S. Oliver (Imperial College, London) the optical spectroscopic follow-up data obtained with the multi-fibres 2dF (Australian Telescope) in the south region called S2 were analyzed. In the same contest of follow-up observation of ELAIS sources, single slit spectroscopic data of faint ISOCAM sources ($\mathrm{Flux}_{15\mu m}$ >0.4 mJy) were obtained using the 3.6m ESO Telescope at La Silla (Chile).

The results of these observation have shown that at brighter ISOCAM fluxes the 15μm band is highly efficient in detecting AGN, especially type 1 at z > 1-1.5. At fainter ISOCAM fluxes the starburst population (including a significant fraction of dust obscured starbursts) is highly dominant, although the redshift distribution for these galaxies shows a peak at much lower z than previously found at similar flux levels in the CFRS ISOCAM survey.

2.3.7 FIRBACK

Involved people at OAB: Ciliegi.

In collaboration with Lagache G. and Puget J.L. (Institute d'Astrophysique Spatiale, Orsay, France), Ciliegi is working on the identification of the FIRBACK sources. FIRBACK is one of the deepest surveys performed at 175 μm with ISOPHOT onboard ISO, and is

aimed at the study of cosmic far infrared background sources. About 300 galaxies are detected in an area of four square degree. Preliminary FIRBACK integral source counts at 175 μm show a strong slope of 2.2 between 120 and 500 mJy. This strong slope is not explained by a K correction or cosmological evolution alone: both must be present. Moreover, SCUBA follow up of FIRBACK sources shown that they are generally detectable in the sub-mm; those with somewhat higher 850 μm flux density may be at z $\sim$ 1, while those which are fainter in the sub-mm may be more normal galaxies at z $\sim$ 0. Model of evolving galaxy populations which provide a fit to the 175 μm counts predict that the median redshift of the FIRBACK sources is around 1. An intensive programme of spectroscopic optical identification of the FIRBACK sources will be carried out during May 2000 at the William Herschel Telescope (WHT) in La Palma (Spain).

2.3.8 Radio observation of the ESP Survey

Involved people 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, Papers I and II accepted by A&A). 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: i) determining the radio properties of ESP galaxies (e.g. radio luminosity function of various types of galaxies), ii) deep radio source counts and optical identification of ATESP sources, iii) 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. It is planned to extend the spectroscopy to much fainter magnitudes in the near future, using the VLT.

2.3.9 Deep Extragalactic Surveys in the Marano Field

Involved people at OAB: Mignoli, Gruppioni, 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 integra-

tion) 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 the future XMM 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 with $S_x > 3.7 \times 10^{-15}$erg-cm^{-2} s^{-1}, one of the deepest existing surveys at these wavelengths. 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. This is consistent with the ROSAT data in the Lockman field, which have shown that at the faintest flux level reached by these observations about 70-80% of the soft X-ray background is resolved into discrete sources (Hasinger, ..., Zamorani 1998, A&A, 329, 482) and about 3/4 of the identifications obtained so far are with classical broad-line AGNs (Schmidt, ..., Zamorani 1998, A&A, 329, 495; Lehmann, ..., Zamorani 1999, A&A, 354, 35). 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. This is confirmed also by the spectroscopic identifications of the X-ray sources in the Lockman field, where a number of the spectra of the faintest AGNs show a substantial contribution from continuum of the underlying galaxy. 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); these are the highest identification fractions available so far in literature for sub-mJy radio samples. This work has suggested that the identification content of the sub-mJy radio sources may be 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. As a consequence, any conclusion on the content of the sub-mJy population based on samples with a large spectroscopic incompleteness does necessarily require significant and uncertain extrapolations of evolutionary models for the different classes of optical counterparts.

• 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 $B = 23.5 \div 24.0$ were selected. A significant fraction of these candidates has been observed spectroscopically with FORS1 at the VLT. Preliminary analysis of these 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 data, when fully reduced, 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.

2.3.10 Radio Observations in the Lockman Hole

Involved people at OAB: Ciliegi, Zamorani.

In January 1999, in collaboration with G. Hasinger (AIP, Postdam), a new deep radio survey a 6 cm in the Lockman Hole has been obtained. The Lockman Field is one of the best studied areas of the sky at all frequencies, from the radio up to the X-ray band. These additional radio data nicely complement the multi–frequency database in this region and allow to push to the faintest possible limit the study of correlations between different bands. The radio observations were carried out with the VLA at 5 GHz (6cm) in the VLA C-configuration in January 1999 (33 hours). A total of 62 sources at $\geq 4.5\ \sigma$ level ($S_{6\ cm} > 50\ \mu$Jy) has been detected. Using the already available deep optical CCD data, 56 of the 62 radio sources (90% !) have been optically identified. Using the V-I versus I-K$'$ color indices plot it has

been found that the radio-to-optical ratio can be reasonably used as a tool to discriminate between $early-type$ and $late-type$ galaxies. The spectroscopic follow-up of these sources is scheduled in May 2000 at the WHT.

2.3.11 Extremely red objects

Involved people at OAB: Pozzetti, Zamorani.

A project aimed at studying the nature of the Extremely Red Galaxies (ERGs) has been initiated in collaboration with Arcetri Observatory. From near-IR (ESO 2.2m+IRAC2) and optical (NTT + EMMI SUSI, HST+WFPC2) imaging data we have selected several ERGs ($R-K>6$ and/or $I-K>5$) both in "empty" fields (Pozzetti et al. in preparation) and around radio-loud AGNs at $z>1.5$ (Cimatti et al. 1999). Most of the HST morphologies of the red selected objects look regular and compact, and only few objects are diffuse or strongly disturbed. The comparison of the observed surface density and color distribution with the predictions from a "monolithic collapse" model shows a deficit of passively evolving ellipticals formed at $z>5$. The contamination of the ERG sample by dust-reddened starbursts and/or AGN has been investigated through near-infrared spectroscopy in order to search for emission lines (e.g. Hα) redshifted in the 1-2.4μm region. A sample of 9 ERGs with $R-K>5$ and $K<19.0$ was observed with the ESO VLT-UT1 equipped with ISAAC. Neither strong emission lines ($F_{lim}<1\div5\times10^{-16}$ erg s^{-1}cm^{-2}) nor continuum breaks were detected. Two of the observed ERGs are dusty starburst candidates because they require strong dust reddening to reproduce their global spectral energy distributions. The other ERGs are consistent with being dustless old passively evolved spheroidals at z>0.8 (Cimatti et al. 1999).

2.3.12 Photometric redshifts

Involved people at OAB: Pozzetti, Zamorani.

In order to study the galaxy luminosity evolution and the star formation history up to $z>>1$, a software to estimate photometric redshifts of faint galaxies has been developed; this revised version of the software will use a complete set of theoretical synthetic spectra

(Bruzual & Charlot 1998), and it will be used to determine photometric redshifts from optical/near-IR survey as well as from the HDF-South, the EIS survey and the VIRMOS deep survey.

2.3.13 The Extragalactic background light

Involved people at OAB: Pozzetti.

In collaboration with P. Madau (IoA, Cambridge), have been investigated the constraints imposed by the observed extragalactic background light (EBL) on the cosmic history of star formation and the stellar mass density today. From galaxy number counts in the UV to K bands (including the *Southern Hubble Deep Field*) a lower limit to the optical EBL of about 15 $nW\,m^{-2}\,sr^{-1}$ was derived, comparable to the intensity of the far-IR background from *COBE* data. A lower limit of $\Omega_{g+s}h^2 > 0.0013\,I_{50}$ can be set to the visible (processed gas + stars) mass density required to generate an EBL at a level of $50\,I_{50}\,nW\,m^{-2}\,sr^{-1}$; our "best-guess" value is $\Omega_{g+s}h^2 \approx 0.0031\,I_{50}$ (Madau & Pozzetti 2000).

2.4 Galaxy clusters and large-scale structure

2.4.1 The Shapley Concentration

Involved people at OAB: Bardelli, Zamorani, Zucca.

Another long term project in which Observatory staff members are 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 higher peculiar velocities induced by the density excess.
A redshift sample of $\sim$ 2000 galaxies has been obtained in the central part of the Shapley Concentration, both in clusters and in the inter-cluster field, allowing a detailed analysis of the properties of this supercluster. On large scales, the geometry, extension, mass and overdensity of the structure were determined, allowing a comparison with the theoretical predictions of different galaxy formation scenarios: the

existence of the Shapley Concentration is consistent only with ΛCDM or open CDM models (Bardelli et al. 2000, MNRAS 312, 540).

Dynamical properties of single clusters in this region were derived (Bardelli et al. 1998, MNRAS 300, 589), as well as their luminosity functions and masses (Bardelli et al. 1998, MNRAS 296, 599): the general conclusion is that the core of the Shapley Concentration is dynamically active, presenting clusters in late stage of merging, as confirmed also by the presence of hot gas filaments between clusters (Bardelli et al. 1996, A&A 305, 435) and of an excess of blue galaxies in the expected position of the shock front.

Moreover, a large field survey at radio wavelengths (with the ATCA and VLA telescopes) has been performed, in order to study the effect of merging on the radio emission of galaxies. The result is that merging "switched off" radio sources, causing a lack of radio galaxies (Venturi, Bardelli et al. 2000, MNRAS 314, 594). In order to investigate the link between radio and X-ray properties in merging clusters, ROSAT and SAX maps were analyzed (Ettori, Bardelli et al. 2000, MNRAS in press) and the physical parameters (temperature, gas distribution and metallicity) of the intercluster medium were derived. The X-ray analysis will be improved by further SAX and XMM observations time already allocated).

Finally, the effect of cluster merging on the galaxy population has been extensively investigated by studying the behavior of the morphology, the [OII] equivalent width and the star formation rate as a function of local density (Bardelli, Zucca & Baldi 2000, MNRAS submitted; Baldi, Bardelli & Zucca, in preparation).

2.4.2 The distribution of galaxies as a function of luminosity

Involved people at OAB: Cappi.

Cappi, in collaboration with C.Benoist, L.N. da Costa (ESO), and S. Maurogordato (Obs. de la Côte d'Azure), has analyzed the statistical properties of the galaxy distribution as a function of galaxy luminosity, using the SSRS2 catalogue (da Costa et al.1994). This analysis has shown that galaxies with $L > L_*$ have an increasingly larger correlation length, approaching that of clusters. However the relative bias in the galaxy distribution is not linear, as clearly shown by Benoist et al. (1999). Moreover, very luminous galaxies approach the cluster correlation length, but they do not seem to reside preferen-

tially in clusters, and their morphological distribution is comparable to the field. A number of these galaxies shows also clear signs of interaction (Cappi et al. 1998). Cappi is studying the dynamics of these systems with observations performed mainly at the OHP 1,93m telescope. Some of these VLGs might be the brightest members of systems similar to the Local Group. He is planning more extensive observations of these systems.

2.4.3 Galaxy systems at $z \sim 0.5$

Involved people at OAB: Bardelli.

The standard CDM model predicts that the evolution of clusters and, in part, of galaxies could be rather rapid and start at relatively modest redshifts. For this reason it is important to perform surveys in the redshift range [0.2 - 0.7].

Concerning the clusters, a spectroscopic follow up of candidate clusters (detected in the EIS survey) started at the ESO telescopes. Using SOFI observations to define a colour-magnitude diagram for galaxies, the most probable cluster members were selected: this approach enhances the efficiency of the EFOSC2 observations (Ramella, ..., Bardelli et al. 2000, A&A in press), which give the definitive redshift of the systems.

Another way to approach the problem is to select groups of galaxies from the ESO-Sculptor survey (deLapparent, .., Bardelli et al. 1997, Messenger 89, 21), a redshift survey limited to R=20.5. The study of the morphology-density relation and of the star formation rate as a function of the environment at these intermediate redshifts will give important information on the galaxy population.

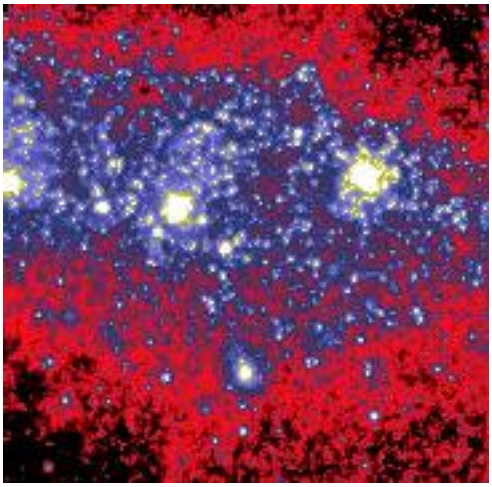
2.4.4 Galaxy clusters and large-scale structure

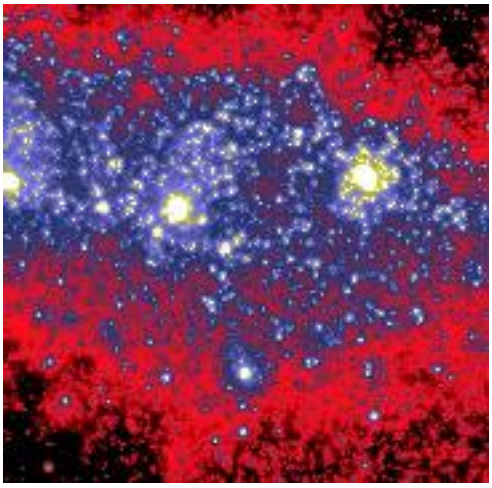
Involved people at OAB: Cappi.

Cappi is involved in a project with researchers at the Observatoire de la Côte d'Azur (Maurogordato, 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 (further observations with XMM are planned). The first results (recently published) of this project concern 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).

3 Numerical studies and software development





Top: *The starburst galaxy NGC 1569 observed with the HST NICMOS camera in the F110 filter.* **Bottom**: *Reconstructed image with the StarFinder algorithm (see section 5.2)*

Involved people at OAB:

- *Scientific staff:* R. Bedogni, P. Londrillo, G. Parmeggiani;
- *Fellows:* E. Diolaiti.

3.1 Turbulence

Involved people at OAB: Bedogni, Londrillo.

Bedogni, in collaboration with A. Di Fazio (Astronomical Observatory of Rome) and V. Urpim (St. Petersburg University), concluded the study of the turbulence in a viscous fluid flow around a sphere by means of numerical 2D simulations. With the derived relation connecting the Reynolds number with the drag function for various Mach numbers, it will be possible to obtain a better modelization of the processes involved in galaxy and star formation.

Bedogni and Londrillo, are exploring numerically the development of turbulence, in order to compare the reliability of the most common numerical schemes used for the solution of the hydrodynamical equations (as, for example, PPM Lagrangean and Eulerian schemes, high order upwind schemes, and so on).

Londrillo, in collaboration with M. Velli and L. Del Zanna (University of Florence), developed a numerical code aimed to an accurate modelization of the solar wind and the consequent clarification of the long-standing problem of the heating of the solar corona. The code can be also applied succesfully to the study of the formation of stellar jets, and, more generally, to the study of compressible turbulence in astrophysical contexts. Moreover, up-wind numerical techniques of high-order in the MHD case have been studied, and applied to the study of the interaction between compressible (shocks) and incompressible (Alfven waves) modes.

3.2 StarFinder

Involved people at OAB: Diolaiti, Parmeggiani.

StarFinder is a code for high precision astrometry and photometry of crowded fields, designed for Adaptive Optics well-sampled diffraction limited images with high and low Strehl ratio. The code is the

result of a joint collaboration between the Astronomy Department of the Bologna University (Orazio Bendinelli and Emiliano Diolaiti), the Working Group on Adaptive Optics at ESO (Laird Close, Douglas Currie and Domenico Bonaccini) and the Bologna Observatory (Gianluigi Parmeggiani). The main peculiarity of the code is the fact that the PSF is extracted directly from the CCD frame, to take into account the actual structure of the instrumental response and the atmospheric effects. The PSF is used as a template for all the stars of the field, which are accepted on the basis of their correlation coefficient with the template. The code has been successfully applied to AO images, like the well-sampled, high Strehl PUEO frame of the Galactic Center, which contains about 1000 detectable stars in a filed of view of 13X13 arcsec^2, to HST undersampled data handled by dithering techniques like the starburst galaxy NGC 1569, observed with the NICMOS camera. The application of the code to low Strehl images or undersampled data gives results comparable to those attainable by other methods. The code is written in IDL language and organized in the form of a self- contained widget-based application, provided with a series of tools for data visualization and analysis. It has been tested on Windows and Unix platforms supporting IDL v.5.0 or later. StarFinder is also reasonably fast: the analysis of the Galactic Center image requires between 5 and 10 minutes on a normal PC (Pentium Pro - 64Mb RAM - 350MHz). The StarFinder package and its technical documentation can be obtained on request to E. Diolaiti (diolaiti@bo.astro.it), writer and maintainer of the code, or are directly available through World Wide Web at the home page of Bologna Observatory.

4 Instruments and Techniques

A detail of the mask cutting machine during the test at the Osservatorio Astronomico di Bologna. This machine is now installed at the Telescopio Nazionale Galileo (TNG)

Involved people at OAB:

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

4.1 Light Pollution

Involved people at OAB: Zitelli.

On spring 1999, the joint working group of the Italian Astronomical Society (SAIt) and UNI (Ente Normatore Italiano) components, after two years of long debate, settled a Technical Standard UNI10919 for the reduction of light pollution. This Standard limits the upward scattered luminous flux emitted by the lighting devices and defines the technical requirements of lighting installations to that purpose. This Standard regards light and lighting, is mandatory only for outdoor new lighting installations and for renewing the existing ones.

4.2 Treatment of astronomical mirrors

Involved people at OAB: Ciattaglia, Mezzini, Zitelli.

A big effort was done in the last years to study the best techniques to remove old aluminum from astronomical mirrors, increasing the cleanness of the glass surface before the new aluminization with minimum risk of chemical and/or mechanical damages. Initial experiments using excimer pulsed laser to ablate old aluminum gave promising results but the tuning of pulse energy to avoid damages to the substrate results so critical, to be considered unrealistic in a operation like the cleaning of a very large mirror. After the decision to return to more conventional chemical treatments, resulting in the selection of an optimal procedure, a prototype of mirror washing machine was built and tested. It permits spraying the proper sequence of chemicals on the surface to remove aluminum, clean, rinse and dry the surface without any direct mechanical action on the surface. An extrapolation of the results of the experiments to 8m mirrors shows that quantities, fluxes

and costs remain in acceptable limits: the procedure can therefore be adopted as starting point for engineering a large dimensions machine.

At present, further experiments are conducted on small mirrors with the surface artificially contaminated by different kinds of dust, simulating different ambients.

4.3 TNG

Involved people at OAB: Zitelli.

Zitelli (with S. Ortolani from Padova, D. Mancini from Napoli, I. Porceddu from Cagliari) is a component of a working group "site testing" for the Telescopio Nazionale Galileo (TNG). Actually, close to the Galileo Site, there are the two towers for the meteo and for the seeing monitor. The analysis of the first data coming from the meteo tower are in progress.

Zitelli (with Held from Padova) is conducting the final test on slit drilling machine for low dispersion spectrograph at the Galileo National Telescope. This Multi Objects Mode is an extended capability complementary to the real time built-in multislit facility and will make possible to obtain simultaneous spectroscopy of many tens of objects over a useful field of 6 arcminx9.5 arcmin.

4.4 The VLT Project

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

The Bologna Astronomical Observatory is involved in the ESO-VLT Project VIMOS. 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 a 1x1 arcmin area. NIRMOS is a near IR imaging spectrograph with a multiplex of 180 (10 arcsec slits), and allows spectroscopy of all objects in a 30x30 arcsec area. Together VIMOS and NIRMOS allow to get spectroscop from 0.37 to 1.8 microns, with unsurpassed efficiency for large surveys.

The Observatory 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 rediced images (both direct imaging and spectra) while the RTD must allow quick-look on the data and a minimal on-line data assessment (see 8.8).

4.5 The Pulsar Project

Involved people at OAB: D'Amico, Innocenti, Sbarbati.

The Bologna Pulsar Group was involved in the last two years in the development of several hardware components in the context of new experiments carried out at the Northern Cross Radiotelescope (Medicina, Italy) and at the Parkes Radiotelescope (NSW, Australia). The experiment carried out at the Italian Cross consists of a large scale survey for millisecond pulsar, and required the assestement and testing of a new powerful online data processing equipment. In the context of the same experiment, a new filterbank and a new digitizer system was constructed and built, to be used for follow-up observations of the Cross discoveries with the 32mt dish available at the same site. In particular, the construction of the new digitiser unit was entirely carried out by Innocenti at the OAB electronic laboratories. The system was successfully commissioned early in 2000 and it it expected to be available as a standard facility by middle 2000.

4.6 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 Osservatorio di Capodimonte 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 a 1 square degree field of view, and is expected to become operative during the year 2002. The camera is built by a consortium of three european institutions and ESO. The instistutions are: Universitaets Sternwarte Muenchen (Germany), NOVA-Kapteyn Instutuut Groningen (The Netherlands) and Osservatorio Astronomico di Padova (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 Laura Greggio, as responsible of the project documentation.

During the year 1999 (ahead of the OmegaCAM Kick-Off meeting, which took place on April 7 and 8, 2000) most of Laura Greggio's work for the project was aimed at creating an efficient way for the communications among the various people participating to the project. She developed a web site, accessible from the Universitaets Sternwarte home page (http://www.usm.uni-muenchen.de) under the title OmegaCAM, which contains all the relevant information/documents that need to be seen/evaluated by all the persons working for the consortium. Laura Greggio is continuously updating the web page, ensuring that the communications are effectively and efficiently maintained within the consortium.

5 Loiano observing site

The 152 cm telescope at the Loiano observing site

Involved people at OAB:

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

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

The **152 cm telescope**, dedicated to G.D. Cassini, was built by Reosc and operates since 1976. 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 and Spectrograph), based on transmitting optics ranging from 330 to 1100 nm. Up to now it is possible to choose, as collecting device, between two CCDs:
2. a Loral thick CCD 2048x2048
3. a Thomson CCD 1024x1024.

   A new camera with a better sensitivity, mounting a chip EEV, is in progress. This camera has been commissioned and will shortly become the standard camera for BFOSC.

   There are two set of filters available: a standard Johnson- Kron-Cuisins system and a Gunn system.
4. A "classical" cooled five colours Photorelectric Photometer
5. A two channels photoelectric Photometer (3 colours).

BFOSC has been the most scheduled instrument for a long time, about 80% of the total allocated time, being its flexibility taking into account the meteo condition of Loiano site.

The **60cm 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 in a f/20 cassegrain and permanently used for photoelectric photometry.

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 Working and use of 152 cm

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

The 152cm telescope *G.Cassini* is available about 350 nights/year. About half of this time is really useful for observations, due to weather conditions. The statistics of this last years is given in table 2. Time is allocated every 6 months, starting in January and July, avoiding excessive fragmentation of observing time, which would be compatible with the typical weather condition of the site. The resident staff is composed by 6 technicians. See par.8.6 to have an updated situation of the Loiano computer facility. It is possible to have a prereduction of the observations with a PC in a local network with the Pc for the observations. MIDAS and IRAF packages are available.

Applications to 152 cm Telescope

1. Gavazzi, G. (Brera) et al.: *The determinations of 106 galaxies redshifts in Virgo cluster*

Table 2. Cassini Telescope – Nights used per year

nights/year	1994	1995	1996	1997	1998	1999
used (t>50%)	133	118	106	122	105	98
used (t<50%)	25	27	26	19	41	22
used for test	23	10	37	32	58	33
not used (weather)	161	169	183	180	142	179
not used (technical)	3	4	3	1	10	4
not assigned	20	37	11	11	10	29

2. Fabbroni et al (OAA): *Calibration spectrum-T-eff for giant cold stars*

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

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

5. De Martino, D. (OAN) et al.: *Photometric variability in polars: SAX-optical observations di AM HER*

6. Silvotti, R. (OAN) et al.: *Whole Earth Telescope campaign on PG1336-018*

7. Lentini, D. (OAM) et al.: *Optical identifications of bright X/radio-sources*

8. Piccioni, A. et al. : *Photoelectric observations of binary stars*

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

10. Valentini, G. (OATe) et al.:*Photometry of old and intermedium age open clusters*

11. Persimoni, A. (OATe) et al.: *The RRLyrae of NGC4147 cluster*

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

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

14. Piccioni, A. et al.: *Fast photometry of X-ray binary CI cam*

15. Di Martino, M. (OATo) et al.: *A search of multiple periodicities in new cataclysmic magnetic asyncrones*

16. Giovannelli, F. (IAS-CNR) et al.: *Spectrophotometric observations of X-ray binaries and interactions with SNRs*

17. Polcaro, V.F. (CNR/IAS): *Slittless spectroscopy and photometry of stars behind the star forming dark clouds*

18. Polcaro, V.F. (CNR/IAS): *Identification and spectroscopic study of re supergiant in open clusters*

19. Marconi, M. et al. (OACd):*Instabilita' pulsazionale nella fase di presequenza: pulsano le stelle Herbig Ae?*

20. Smart, R.L. (OATo) et al.: *Photometry of parallactic fields*

21. Focardi, P. (Univ. Bologna) et al. : *A new sample of galaxy pairs*

22. **Stirpe, G.M.** et al.: *Photometric monitoring of AK 564*

23. Simon, V., Hudec, R. (Ondrejov Obs. Czeck. Rep.): *Photometric and spectroscopic observations of objects related to RGB and close binaries containing a compact object*

- Application for undergraduate students of astrophysics:

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

- Tests:

    1. Silvotti, R.: *TTCP photometer*

Scientific productions involving the 152 cm Telescope

1. Gavazzi, G. et al.: *The 3-D structure of the Coma - A 1363 supercluster: optical spectroscopy of 102 galaxies*, A&A Suppl., 136, 227-235 1999

2. Giovannelli, F. et al.:*IAU Circ. n.7293, 1 1999*

3. Gaudenzi, S., Polcaro, V.F. : *The peculiar M giant HD 154791 optical counterpart of the X-ray source 4U1700+24*, A&A, 347, 473-477 1999

4. Israel, G.L. et al.: *The identification of the long period X-ray pulsar 1WGAJ 1958.2+3232 with Be star/Xray binary*, A&A, 345, 745-755 1999

5. Silvotti, R. et al.: *The photometric behavior of the peculiar PG1159 star HS 2324+394 at high frequency resolution*, A&A, 342, 745-755 1999

6. Guarnieri, A. et al.: *An optical counterpart to GRB 971227?*, A&A Suppl., 138, 475-458 1999

7. Piccioni, A. et al.: *Photometry and spectroscopy of X per during the years 1996-1999*, IAU Coll. 175, vol.28

8. Piccioni, A. et al.: *Spectral and photometric evolution of V725 TAU (1996-1999): towards a shell phase?*, IAU Coll. 175, vol.28

9. Bernabei, S. and Polcaro, V.F. : *Old spectral type stars in young clusters*, Frascati workshop 1999 *The changes in abundancies in asymptotic giant branch stars*

10. Piccioni, A. et al.: *Search for pulsational instability on sdB and sdO stars* Frascati workshop 1999 *Multifrequencies behavior of high energy*

11. Israel, G.L., Covino, S., Polcaro, V.F., Stella, L., 1999, *The identification of the long-period X-ray pulsar 1WGA J1958.2+3232 with a Be-star/ X-ray Binary*, A&A, 345, L1

12. Gaudenzi, S., Polcaro, V.F., 1999, *The peculiar M giant HD 154791. Optical counterpart of the X-ray source 4U1700+24*, A&A, 347, 473

13. Polcaro, V.F., Norci, L., Rossi, C, Viotti, R. *On the so called WO stars*, in *WR phenomena in massive stars and starbust galaxies*, K. van der Hucht et al. (eds.), Reidel, 1999

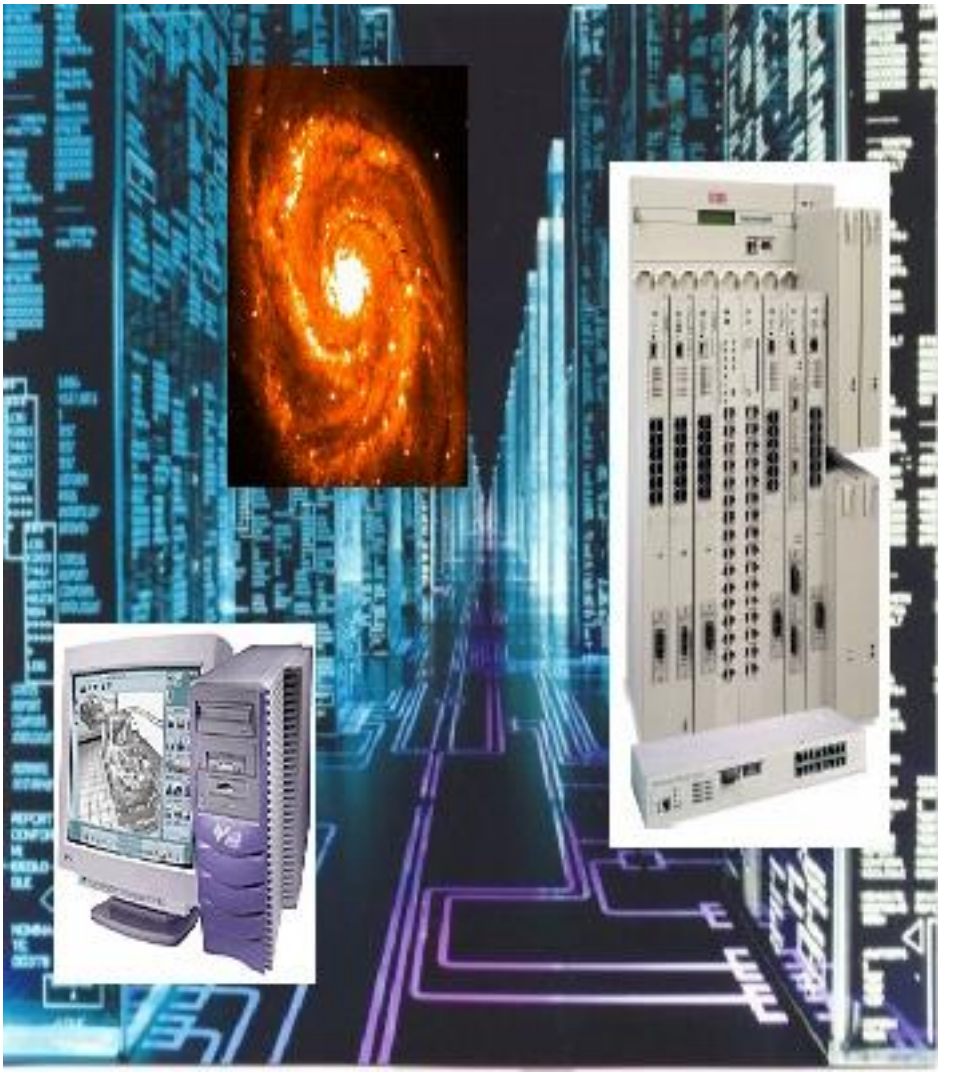
14. Persi, P., Polcaro, V.F., Bohigas, J., Tapia, M., IAU Coll. 175, Alicante, 28 June - 1 July 1999

15. Israel G.L., Covino, S., Polcaro, V.F., Campana, S., Stella, L., Pizzella, A., IAU Coll. n.175, Alicante, 28 June - 1 July 1999

16. Bernabei, S., Polcaro, V.F., *The change in abundance in asymptotic giant branch stars*, M. Porzio, 16-18 September 1999

17. Polcaro, V.F., Gupta. R., Singh, H.P., Sen, A., *Workshop Nazionale sui piccoli telescopi*, M. Porzio, 14-15 December 1999

6 Computer center and computer network



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, G. Bregoli, A. Marchesini.

6.1 Introduction

Between the last months of 1998 and the first half of 1999 the personnel of the Bologna Astronomical Observatory and the Department of Astronomy of the University of Bologna moved to the new building in via Ranzani. Part of the people of both institutions were already working in a portion of the structure but the transfer of the whole personnel implied moving all the computers at the time hosted in the old tower in via Zamboni. The definition of the new logistic for the hardware, the re-wiring of the computer network and the re-installation of all the computers required a strong effort for the computer center staff.

The layout of the new building, much more rational than the eighteenth century tower, improved the distribution of the common facilities of the computer center and also the performance of the network.

During the year, computer facilities have been upgraded as far as both cpu power and network are concerned. Some new people have joined the computer center staff adding support for the maintenance of the informatic lab and for the numerical analysis and data reduction fields.

In the second half of 1999 a consistent part of the computer center activity was addressed to the upgrade of the workstations operating systems to comply with the Y2K problem.

6.2 Computer center improvements

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

During 1999 the hardware update of the computer center was continued. The number of Alpha workstations, replacing the old Digital

DECstation, was increased together with the number of PCs used as a front-end of more powerful servers, instead of dated X-terminals or as stand-alone workstations for data reduction under Linux OS.

Given the always increasing dimension of astronomical images, several workstations were upgraded both in physical memory and disk space in order to improve their performances.

The increase in the number of workstations has decreased the amount of users per workstation, but has raised the work-load of the computer center staff. For this reason, a series of lessons on the basics of System Management were organized, in order to allow a group of users to help the staff to solve the simpler management problems.

Furthermore, a new server, especially configured in memory and disk space for dealing with the huge amount of data expected from the new national and international telescopes (ESO-VLT, TNG), has been installed. Also a Sun Ultra 5 workstation has been bought and made available. It will be primarily used to run the ESO P2PP procedure and secondly to run software compatible with this architecture only. The actual list of workstations is the following:

Name	Model	Users
Aspera	PWS 422	D'Ercole/Brighenti
Boas5	AlphaServer 2000/275	General Purpose
Boas4	AlphaStation 3000/300	Mignoli/Marano/Merighi/Pozzetti
HST	AlphaStation 200 4/166	Dedicated to HST data reduction
Zeus	AlphaStation 200 4/266	Ferraro/Fusi Pecci
Boas6	AlphaStation 3000/300	Federici/Bragaglia
Sean	AlphaStation 255/300	Tosi/Clementini
Kennet	AlphaStation 255/300	Stirpe/DeRuiter/Comastri/Palumbo
Zorro	AlphaStation 255/300	D' Ercole/Ciotti
Naomi	PWS 500	Bedogni
Hal	AlphaStation 200 4/166	Giovannini
Luna	PWS 433	Pellegrini/Ciotti
DNS	Alpha 500/266	WWW/network server
Vega	PWS 433	Bartolini/Guarnieri
Arianna	PWS 500	Greggio/Tosi
Avalon	PWS 500	Ciliegi
Gemini	AlphaServer 4100	Data reduction/ General Purpose
Apache	XP 1000	Ferraro
Hopi	Alpha 255/233	Origlia/Bellazzini
Tucanae	Alpha 500/500	D'Amico
Excalibur	Alpha PW 433	Zucca/Bardelli/Cappi
Cronopio	Alpha PW 433	Montegriffo
Gaia	PWS 500	Federici/Bragaglia
FFT0/1/2/3	PWS 500	D'Amico
Eclipse	Sun Ultra 5	ESO P2PP
Vimos	HP 9000	Vimos project

Two VAX/VMS hosts (ASTBO3 e ASTBO4) are still in activity, being used as central units.

The first is mainly used by the personnel of O.A.B. and Astronomy Department. The second one by the students.

The number of PCs used as Unix-Linux workstations increased during 1999 reaching the number of 15 units, plus 10 PCs running Win98.

6.3 Improvements in the local network

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

The network hardware installed in the via Ranzani building, before the Observatory move, was a 10Mb/s *switched* lan. After the move,

similar *switches*, installed in the tower, were ported to the new wing of the building to cover the need for new connections. Moreover the older hardware has been updated and expanded to make it homogeneous with respect to the one installed in the new building. In the new wing, thanks to a joint-project between Department of Astronomy and Osservatorio Astronomico, based on a grant from the University of Bologna, a new Cabletron *switch* operating at 100Mb/s, has been installed. This *switch* is connected in ATM on optical fiber (155Mb/s) to the academic network, the GARR backbone and to the switches of the old wing allowing the connection of the whole building.

Concerning the Astronet project, a new Alpha 500/266 workstation has replaced the VAX/VMS 4090. This workstation hosts the national DNS and the WWW Observatory site.

6.4 Improvements in the geographic network

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

6.4.1 Computer networks

Involved people at OAB: Delpino, Di Luca.

In the past two years relevant aspects of computers networks both at local (LAN) and geographical (MAN and WAN) level have been examined, 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 a static or dynamic partition of the band.
That 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). In this context a development model for the project of the new metropolitan research network of the Bologna town has been drawn up. That is based on an 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 summer of the year 2001.

6.4.2 Web applications

Involved people at OAB: Delpino, Lolli.

The need of realizing Web applications has implied a great interest in the field of object programming, with particular reference to the Java language. That in fact presents well definite advantages as one is interested in developing platform independent and/or 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 are then studied and compared (Active Server Pages, Servlets, Java Server Pages).

6.5 Improvements in the accessory services

Involved people at OAB: Di Luca, Merighi.

Concerning accessory services improvements, a new high-quality network printer LN20 (17 ppm, 600dpi, auto-duplex unit) has been bought. Also a color PostScript laser printer HP4500N, a DLT juke-box backup unit (7 x 20/40 GB tapes) and a Panasonic video-beam (twin-lamp, 1024x768 resolution , ceiling-mounted in the conference-room) have been bought on an Astronet grant from the Department of Astronomy.

The necessity of a color laser printer comes from the need to obtain presentation-quality transparencies, better than the ones produced by ink-jet printers already available.

The DLT juke-box has been bought to allow automatic backups on workstations with several GB of disk space. Nowadays EIDE or

SCSI disks with 20-30 GB of capacity are commonly available and it would be impractical to back them up on DAT media.

The video-beam completes the conference-room equipment, as the use of slide-shows and computer-presentations during seminars and conferences has become quite common.

6.6 Loiano station

Involved people at OAB: Lolli.

At the Loiano telescope several PCs have been replaced with more efficient machines. In particular, the Alpha 2000 4/266 workstation was replaced with a PC Pentium III 600MHz with 512 MB RAM running Linux. The standard data reduction packages (IRAF, MIDAS, SM) have been installed on it. This computer has also been equipped with a Plextor CD writer to produce the telescope image archive CD-ROMs.

6.7 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 licences, 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

6.8 Other activities

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

The computer center staff has carried on other activities during 1999. Among them:

- Participation to ESO-VLT projects. Personnel of the computer center are collaborating in the ESO-VLT VIMOS project, developing software for the data reduction. The software will be integrated in the automatic pipe-line procedure to provide completely calibrated data from the instrument. The software developed addresses the imaging data reduction and the astrometric correction.
- Original software for data analysis in digital photometry in crowded fields and variable star data analysis.
  In the field of variable stars data analysis the programs GRATIS (variable stars analysis), VARFIND (identification and analysis of candidate variable starts in big data set), VARCAT (variable starts archive on the local alpha workstation network) and ATMOS (Baade-Wesselink method applied to photometric data from variable stars).
  In the crowded fields digital photometry subject, the CATAPACK program (management of photometrics catalogues) has been developed and automatic pipelines have been written for the study of the completeness factor and photometric analysis on HST data set.

7 Library

Guido Horn d'Arturo (1879-1967)

Involved people at OAB:

- *Library staff:* M. Ferrarini, M. Marra.

The "Guido Horn d'Arturo" Library (http://www.bo.astro.it/∼biblio/nuova-biblio/frame.html) is managed jointly by the Department of Astronomy of the Bologna University and the Bologna Astronomical Observatory, according to the agreement between the two institutes for the sharing of facilities.

In 1999 the two main events were the transfer of all library stock and facilities from the ancient site of via Zamboni - where they had lain for more than two hundred years - to a new building in a nearby area, and the dedication of the library to the memory of Guido Horn d'Arturo.

The former event required a notable effort, as it implied not only a huge move, but also a complete re-organization of the library stock. This has been located in the new premises according to a more rational and user-friendly scheme, now entirely in accordance with the alphabetical order for as much as the reading rooms are concerned.

The dedication of the library to Guido Horn d'Arturo took place on June 14th, during a celebration ceremony.

The "Guido Horn d'Arturo" library dates back to the foundation of the Observatory of Bologna in the early XVIII century, and nowadays is specialized in astronomy and astrophysics. It now owns about 6000 modern books, receives more than 90 specialized serials, has an important historical section, a section of non-book materials, a notable collection of publications by both Italian and foreign astronomical observatories.

The library provides access to all the available full-text electronic editions of journals for which there is a paper subscription. It has a computer catalogue of monographes and grey literature which is available online (telnet session) and is part of various collective OPACs: SBN (Servizio Bibliotecario Nazionale), CUBAI (Catalogo Unico delle Biblioteche Astronomiche Italiane), ACNP (Archivio Collettivo Nazionale Periodici). With regard to ACNP, 1999 marked the end of an important task: the cataloguing of all the periodicals and publications of astronomical observatories and institutes in stock was completed (up to a thousand records now in ACNP). The library offers a document delivery and interlibrary loan service (in 1999: 119 papers supplied,

28 requested from other libraries; 6 interlibrary loans; 184 opuscula and catalogues of exhibitions sent out). The library recognizes as its primary users the students of the Astronomy course at the University of Bologna and local astronomers. It also provides documents to amateur astronomers, school teachers and scientists, such as physicists, historians and philosophers of science. Students from the scientific Departments of the University of Bologna are welcome. Registered users are about 680 ($\sim$ 1500 borrowings in 1999).

The antique section owns most of the publications written by the astronomers of Bologna since the XVIII century, e.g. the "Schedae Mathematicae" by Vittorio Stancari, the "Ephemerides Bononienses" and other works by Eustachio Manfredi, Eustachio Zanotti, Ignazio Calandrelli (Rome, 1792-1866). It includes books of the private library of Manfredi and several older books, of XVI and XVII centuries, of general astronomical interest (Tycho Brahe's "Astronomiae instauratae mechanica", Kepler's "Astronomia nova", Copernicus' "De revolutionibus" and many others). Close to the astronomy library are the Archives (http://www.bo.astro.it/$\sim$biblio/Archives/copertina.htm), a remarkable collection of documents, meteorological and astronomical observations, papers and drawings related to the scientific and administrative life of the Bologna Observatory dating back to 1679. In 1999 the antique section registered 23 consultations of antique books or archives documents, 20 requests for bibliographic information; 14 requests for microfilming books or documents.

Librarians handle acquisitions, inventory, cataloguing, bibliographic researches (both paper and online), maintain the Web page of the library (http://www.bo.astro.it/$\sim$biblio/nuova-biblio/frame.html) and edit the online version the Astronomical Observatory and Astronomy Department Bologna Astrophysical Preprints (http://www.bo.astro.it/bap/BAPhome.html); they collaborate in outreach activity involving Loiano telescopes; they follow professional courses organized by the University of Bologna and other institutions and associations, and train part-time students employed in the library.

The staff included people from the Department of Astronomy: Marina Zuccoli, Chief librarian (Department of Astronomy), Pietro Candelaresi, Assistant librarian (Department of Astronomy), Monica Ferrarini, Assistant librarian (Bologna Astronomical Observatory), Monica Marra, Assistant librarian (Bologna Astronomical Observatory).

8 Informative and educational activities

The brochure for the public event organized by the OAB during the Sun Eclipse in August 99

Involved people at OAB:

- *Scientific staff:* Marano, Parmeggiani, Zitelli, Bedogni, Cappi, Ciotti, Clementini, D'Ercole, Ferraro, Fusi Pecci, Sancisi, Delpino.
- *Technical staff:* De Blasi, Di Luca.

The Astronomical Observatory of Bologna (OAB) has always been involved in research activities. For the last years the OAB has been concentrating in educational and informative activities through seminars, exhibitions and radio/tv programs. The growth of public interest towards astronomy and astrophysics has developed a stable partnership between OAB and other institutions like Radioastronomic Observatory (CNR Bologna), Planetarium of S. Giovanni in Persiceto (Bo). *Il parco delle stelle* and *Con il laser tra le stelle* are two of the successful activities initiated during 1996-1997. Amongst the most recent ones, we find the following:

8.1 Col Favore del Buio

Involved people at OAB: Marano, Parmeggiani, Zitelli, De Blasi, Di Luca.

The collaboration between the Astronomical Observatory, Assessorato Provinciale alla Cultura and the Loianos council leaded, a few years ago, to the creation of *Il Parco delle Stelle*. This event is now managed by Parmeggiani and Zitelli. With che collaboration of a group of astronomers they organize views of the most magnificent objects of our skies using the well-known 60-cm Telescope of Loiano built in 1936. Although this Telescope has often been modernised, it has kept its original main structure and techniques. After this session 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 any questions. Starting from 1998 all sorts of new technologies have been introduced to this activity like multimedia-programs. Nowadays *Il Parco delle Stelle* is included in the activity *Col Favore del Buio* and it works very closely with the Radioastronomic 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 incredibly successful that the schedule for this year includes 54 evening sessions with over 1500 visitors. Both the 60 cm and the 1.52 m telescope (G.D. Cassini) can be visited during the day. G.D Cassini is open to public view on the first Saturday of the month and, prior booking only, any other day.

8.2 Con il laser tra le stelle

Involved people at OAB: Marano.

With the great help of the Loianos council, every 10th of August the Astronomic Observatory of Bologna organizes an evening dedicated to Perseidis meteor 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 the Astronomical Observatory. For about 2 hours, with the help of a laser, Prof. B. Marano shows the visitors how to orientate themselves in the dark skies.

8.3 Leggere il cielo

Involved people at OAB: Parmeggiani.

In 1998 the OAB has organized a training course for primary and high school teachers. This event, called *Leggere il Cielo*, was sponsored by Bolognas council and managed by dott. G. Parmeggiani. 120 teachers applied for this seminar but OAB could accept only 40; this number was than stretched to 48 to accommodate the great demand (15 teachers from primary schools, 17 from middle and 16 from high school). The course was held for 8 weeks, each session lasted for 3 hours. In 1999 this project developed in something a bit more sophisticated. It was divided into 2 modules one of which aimed to develop the knowledge of specific planets and galaxies. The first module, divided into 6 weekly meetings for a total of 18 hours, was attended by 46 teachers (19 from primary schools, 15 from middle and 12 from high schools); 30 teachers attended the second module (2 from primary school, 3 from middle and 25 from high schools). The Astron-

omy journal S.A.It. has published a supplement summarizing these lessons. This article explains very clearly and in a simplistic way these various astronomic topics and it is available to the public. Amongst the attendance we find the following professors: C. Bartolini, P. Battistini, R. Bedogni, F. Bonoli, A. Cappi, L. Ciotti, A. G. Clementini, D'Ercole, B. Marano, F. Ferraro, G. Palumbo, F. Fusi Pecci, R. Sancisi, A. Turricchia, V. Zitelli.

8.4 Sun Eclipse 1999

Involved people at OAB: Parmeggiani, Zitelli, De Blasi.

On the 10th August 1999 the OAB, with both Loiano and Bologna council, has organized a big public event to enjoy the famous sun eclipse. Loianos football field and Giardini Margherita of Bologna were packed with thousands of people who attended this fantastic event and took advantage of the expertise of A. De Blasi, S. Galleti, G. Parmeggiani, A. Turricchia and V. Zitelli. This event has been closely followed by the media, in particular by Rete7.

8.5 IperAstro

Involved people at OAB: Bedogni, Delpino.

IperAstro is another project started by the OAB (dr. R. Bedogni and dr. F. Delpino) and Department of Astronomy (prof. F.S. Delli Santi and F. Zavatti) with the objective to develop the study of astronomy within the schools and anybody else who might be interested in this subject. This study was divided into 10 different lectures and several tests. IperAstro was developed with the very well famous language HTML and it runs with browsers like Netscape or Internet Explorer (http://naomi.bo.astro.it/∼bedogni/demo.htm).

8.6 Edgar Allan Poe

Involved people at OAB: Cappi.

Cappi is also interested in various aspects of the history of cosmology; in particular, he has clarified the interest of the evolutionary newtonian cosmology of Edgar Allan Poe.

9 List of Publications

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10 Observing Campaigns

Radio Telescopes

1. VLA–5GHz: PI: **Ciliegi, P.**, CoIs: **Comastri, A.**, Vignali, Fiore, Giommi, Antonelli; *6cm radio observations of the HELLAS X-ray sources*; 18 hours (Conf C) (April 2000).

2. ATCA–5GHz: PI: **Ciliegi, P.**, CoIs: **Comastri, A.**, Fiore, Giommi, Antonelli; *Radio observations of the HELLAS X-ray sources*; 24 hours (Conf 6.0A) (June 1999).

3. VLA–5GHz: PI: **Ciliegi, P.**, CoIs: **Zamorani, G.**, **Gruppioni, C.**, Giacconi, Hasinger, Trumper, Schmidt; *A Deep VLA Survey at 6 cm in the Lockman Hole*; 33 hours (Conf C), (January 1999).

4. PARKES–1.4 GHz: PI: **D'Amico, N.**, CoIs: Lyne A.G., Possenti A., Manchester R.N., Camilo F.; *A search og the Globular Cluster System for millisecond pulsars*; 3 days (Jan-Apr 1999) + 2 days (May-Ago 1999) + 3 days (Sept-Dic 1999).

5. PARKES–1.4 GHz: PI: Lyne, CoIs: Manchester R.N., **D'Amico, N.**, Kaspi V.M., Camilo F., Possenti A., Stairs I.S. et al.; *Multibeam Pulsar Survey of the Galactic Plane*; 25 days (Jan-Apr 1999) + 28 days (May-Ago 1999) + 24 days (Sept-Dic 1999).

6. ATCA–5 GHz e 8.4 GHz: PI: T.Venturi, CoIs: **Bardelli, S.**et al.; *Extended radiogalaxies at the center of the Shapley Concentration*; 24 hours (config 375m) + 24 hours (config 1.5C) (Gen 1999, May 1999).

HST

7. HST–STIS: PI: **Stanghellini, L.**, CoIs: ...; *A SNAPSHOT Survey of LMC Planetary Nebulae: a study of nebular and late stellar evolution*; 50 orbits (snapshot mode, cycle 8).

8. HST–STIS: PI: **Stanghellini, L.**, CoIs: ...; *Survey of SMC Planetary Nebulae: nebular and stellar evolution in a low-metallicity environment*; 55 orbits (snapshot mode, cycle 9).

9. HST–WFPC2: PI: R. A. Shaw, CoIs: ..., **Stanghellini, L.**, ...; *The most elusive nuclei of LMC Planetary Nebulae*; 20 orbits (snapshot mode, cycle 9).

10. HST–STIS: PI: F. Palla, CoIs:... **Stanghellini, L.**, ...; *The 12C/13C abundance ratio in NGC 3242* ; 5 orbits (GO mode, cycle 9).

11. HST: PI: **Tosi, M.**, CoIs: ...; *NGC1705: a benchmark for galaxy evolution*; 18 orbits (Sept 1999, Nov 2000).

12. PI: **Tosi, M.**, CoIs: ...; HST: *Starbursts: The first generation*; 13 orbits (Mar 1998, Mar 1999).

13. HST: PI: C.Leitherer, CoIs: **Tosi, M.**, ...; *The α-element/iron ratio in Starburst populations*; 18 orbits (Apr 2000, Dec 2000).

14. HST + WFPC2: PI: **Ferraro, F.R.**, CoIs: B. Paltrinieri, R.T. Rood, R. Buonanno, **Cacciari, C.**, R.W. O'Connel, B. Dorman; *UV light from old stellar populations: a census of UV bright stars in "Blue Tail" Globular Clusters*; 13 orbits.

ESO

15. ESO– 2.2m/WFI: **Large Programme**, PI: Arnaboldi, CoIs: De Martino, Garilli, Guzzo, Le Fevre, Maccagni, Mazure, Picat, Scaramella, Vettolani, **Zamorani, G.**; *A deep + shallow U imaging survey: preparation to the VIRMOS Deep redshift Survey*; 2 nights (Mar 1999), 3 nights (Apr 1999), 2 nights (Sept 1999), 3.4 nights (Nov 1999), 2 nights (Mar 2000), 1 night (May 2000), 3 nights (Aug 2000).

16. ESO–VLT1: PI: Bianchi, L.; CoIs: Chandar, R., **Cacciari, C.**, Ford, H., Romaniello, M.; *The formation and evolution of NGC6822 through its stellar clusters*; 9.6 hours (service mode).

17. ESO–3.6m + AdonisH: PI: Bonaccini, D., CoIs: **Ferraro, F.R.**, Currie, D., Diolaiti, E., **Parmeggiani, G.**, Bendinelli, O.; *Large population studies of Globular Clusters*; 2 nights (27-28 Jun 1999).

18. ESO–1.5m: PI: **Bragaglia, A.**, CoIs: **Tosi, M.**; *High-res spectroscopic study of old open clusters as tracers of Galactic chemical evolution*; 4 nights (Apr 2000).

19. ESO–VLT2: PI: **Cacciari, C.**; CoIs: **Bellazzini, M.**, **Fusi Pecci, F.**, Messineo, M.; *Cataclismic variables and faint UV stars in the globular cluster NGC288*; 13 hours (service mode).

20. ESO–1.5D: PI: **Cacciari, C.**; CoIs: **Bellazzini, M.**; *The RR Lyrae variables in the Sgr globular cluster M54*; 4 nights (13-15/07/99, 18-20/07/99).

21. ESO–VLT + FORS1/ISAAC: **Large Programme**, PI: Cimatti, A., CoIs: Broadhurst, T., Cristiani, S., D'Odorico, S., Daddi, E., Fontana, A., Gilmozzi, R., Menci, N., **Pozzetti, L.**, Renzini, A., Saracco, P., **Zamorani, G.**; *A stringent test on the formation of early type and massive galaxies*; 7+2 nights (Oct, Nov 1999).

22. ESO–VLT + ISAAC: PI: Cimatti, A., CoIs: Renzini, A., Andreani, P., Di Serego Alighieri, S., Mannucci, F., Oliva, E., **Pozzetti, L.**, Röttgering, H., Villani, D., **Zamorani, G.**; *ISAAC spectroscopy of Extremely Red Galaxies*; 2 nights (Apr 1999).

23. ESO–NTT + SOFI: PI: D'Antona, F., CoIs: **Origlia, L.**, Oliva, E., Natta, A., Palla, F.; *A search for old, methane-dominated brown dwarfs*; 3 nights (13-15 May 2000).

24. ESO–2.2m + WFI: PI: **Ferraro, F.R.**, CoIs: Paltrinieri, B., **Fusi Pecci F.**, **Cacciari, C.**; *Large population studies of Globular Clusters*; 2 nights (22-23 Jan 1999).

25. ESO–2.2m + WFI: PI: **Ferraro, F.R.**, CoIs: Paltrinieri, B., Buonanno, R., Rood, R.T.; *Large population studies of Globular Clusters. II*; 2 nights (10-11 Jul 1999).

26. ESO–VLT1 + FORS1: PI: **Ferraro, F.R.**, CoIs: Testa, V., De Marchi, G., Paresce, F., Pulone, L., Buonanno, R.; *The mass function of intermediate age clusters in the Magellanic Clouds: a step toward the determination of the true nature of the IMF*; 10 hours (1 Oct 1999).

27. ESO–2.2m + WFI: PI: **Ferraro, F.R.**, CoIs: Testa, V., **Origlia, L.**, Maraston, C.; *Near infrared imaging of Magellanic Cloud Clusters: investigating the spectral evolution of stellar populations*; 3 nights (12-14 Jan 2000).

28. ESO–NTT + SUSI2: PI: **Ferraro, F.R.**, CoIs: Pancino, E., Pasquini, L., Piotto, G., **Bellazzini, M.**, Zoccali, E.; *Solving the omega Centauri mystery: do the metal rich component belong to a merged cluster?*; 7.8 hours (1 Apr 2000).

29. ESO–NTT + EMMI: PI: **Ferraro, F.R.**, CoIs: Pancino, E., Pasquini, L., Piotto, G., **Bellazzini, M.**, Zoccali, E.; *Solving the omega Centauri mistery: do the metal rich component belong to a merged cluster?*; 2 nights (12-13 Apr 2000).

30. ESO–2.2m + WFI: PI: **Ferraro, F.R.**, CoIs: Pancino, E., Paltrinieri, B., Buonanno, R., Rood, R.; *Large population studies of Globular Clusters. III*; 3 nights (6-8 Jul 2000).

31. ESO–3.6m: PI: Fiore, F., CoIs: **Comastri, A.**, Vignali, C., La Franca, F., Matt, G., Antonelli, L.A., Maiolino, R., Molendi, S., Giommi, P.; *The luminosity function of hard X-ray selected sources*; 3 nights (Jul 2000).

32. ESO–1.5D+3.6m: PI: Gratton, R.G.; CoIs: Carretta, E., **Clementini, G.**, **Bragaglia, A.**; *Metal abundances for RR Lyrae in the LMC*; 4+2 nights (4-7/01/99, 17-18/01/99).

33. ESO–VLT2: **Large Programme**, PI: Gratton, R.G.; CoIs: Bonifacio, P., **Bragaglia, A.**, Carretta, E., Castellani, V., Chieffi, A., Claudi, R., **Clementini, G.**, D'Antona, F., Desidera, S., Francois, P., Grundhal, F., Molaro, P., Pasquini, L., Sneden, C., Spite, M., Spite, F., Straniero, O.; *Distances, ages, and metal abundances in Globular Cluster Dwarfs*; 12 nights (16-22/06/2000, 5-11/09/2000).

34. ESO–3.6m + EFOSC2: PI:**Gruppioni, C.**CoIs: **Ciliegi, P.**, Lari, **Mignoli, M.**, Pozzi, La Franca, Oliver, Rowan-Robinson; *CCD imaging and Optical Spectroscopy of ISO LW3 sources in the ELAIS deep test region S2*; 2 nights (5-6/12/99)

35. ESO–2.2m: PI: Held, E.V.; CoIs: **Cacciari, C.**, **Federici, L.**, Testa, V.; *Stellar populations in extragalactic globular clusters: the galaxy sample*; 2 nights (03-05/03/2000).

36. ESO–VLT1: PI: Held, E.V.; CoIs: **Federici, L.**, **Cacciari, C.**, Testa, V.; *The ages and abundances of globular clusters in the Sombrero galaxy*; 11 hours (service mode).

37. ESO–NTT + SOFI: PI: Le Fevre, CoIs: Arnaboldi, Cuby, Garilli, Iovino, Maccagni, MacCracken, Mazure, Picat, Saracco, Scaramella, Tresse, Vettolani, Zanichelli, **Zamorani, G.**; *A deep J & K imaging survey: preparation to the VIRMOS Deep Redshift Survey*; 2 nights (Apr 1999), 3 nights (Sept 1999), 3 nights (Nov 1999), 2 nights (Apr 2000), 1 night (May 2000), 4 nights (Sept 2000).

38. ESO–VLT1 + FORS1: PI: Le Fevre, CoIs: Vettolani, Arnaboldi, Mellier, Cuby, Deltorn, Mazure, Le Brun, Guzzo, Maccagni, Scaramella, Tresse, **Zucca, E.**; *A redshift survey of 150 $I_{AB} < 24.5$, $K_{AB} < 23.5$ galaxies: evolution of galaxies from z=0.6 to z=5*; 8 hours (service mode, Apr 2000).

39. ESO–VLT1 + ISAAC: PI: Oliva, E., CoIs: Moorwood, A.F.M., **Origlia L.**, Maiolino, R.; *The stellar mass–to–light ratio of Seyferts and the starburst–AGN connection*; 2 nights (29-30 Mar 2000).

40. ESO–VLT1 + ISAAC: PI: Oliva, E., CoIs: **Origlia, L.**, D'Antona, F., Maceroni; *C12/C13 and O16/O17 ratios in O-rich HBB-AGB stars of the Small Magellanic Cloud*; 14 hours (1 Apr 2000).

41. ESO–NTT/2.2m: PI: Pasquini, L.; CoIs: **Cacciari, C.**, Andersen, J., Cutispoto, G.; *Eclipsing binaries in globular clusters: omega Cen*; 4+1 nights (24-29/04/99).

42. ESO–VLT1 + FORS1: PI: Paresce, F., CoIs: Baraffe, I., Buonanno, R., Chabrier, G., De Marchi, G., **Ferraro, F.R.**, Pulone, L.; *The mass function of Globular Clusters and its evolution*; 12 hours (1 Apr 1999).

43. ES0–3.6m + EFOSC: PI: Ramella, M., CoIs: **Bardelli, S.**, **Zucca, E.**et al.; *Spectroscopy of intermediate redshift EIS candidate clusters*; 5 nights (Apr 2000, Sept 2000).

44. ESO–2.2m + WFI: PI: Ramella, M., CoIs: **Bardelli, S.**et al.; *The luminosity function of groups of galaxies at z$\sim$ 0.1*; 10 hours (Apr-Sept 2000).

45. ESO–3.6m + EFOSC: PI: Ramella, M., CoIs: **Bardelli, S.**et al.; *The realm of distant EIS Clusters*; 2 nights (Feb 1999).

46. ES0–3.6m + EFOSC: PI: Ramella, M., CoIs: **Bardelli, S.**et al.; *Spectroscopy of groups of galaxies at z$\sim$ 0.1*; 3 nights (Sept 1999).

47. ESO–2.2m, P.I.: Saviane, I.; CoIs: Held, E.V., **Clementini, G.**, Di Fabrizio, L., Momany, Y.; *The old populations of dwarf galaxies: a search for RR Lyrae variables in Leo I and NGC 6822*; 4 half nights (22-25/04/2000).

48. ESO–NTT: PI: **Stanghellini, L.**; *follow-up spettroscopico delle PN nelle nubi di Magellano*; 4 nights (Oct 1999).

ESO–VLT1: PI: Tolstoy, E., CoIs: **Tosi, M.**e **Greggio, L.**; *The star formation history of the Local Group: making the connection to high redshift*; 3 nights (Jul 1999).

49. ESO–: PI: **Zamorani, G.**CoIs: Aussel, H., Cimatti, A., **Gruppioni, C.**, Hasinger, G., **Marano, B.**, **Mignoli, M.**, **Pozzetti, L.** # 64.O-0331(B); *Optical spectroscopy of faint AGN candidates in the "Marano Field"*; 16 hours (Service Mode: Oct 1999 - Jan 2000).

TNG

50. TNG: PI: Daddi, E., CoIs: Di Serego Alighieri, S., Cimatti, A., **Pozzetti, L.**; *A photometric search for z ¿ 1.5 clusters of galaxies*; 3 nights (Mar 2000).

51. TNG + ARNICA: PI: **Ferraro, F.R.**, CoIs: **Origlia, L.**, Paltrinieri, B., Oliva, E., Rood, R.T.; *Multi-Band population studies of Glactic Globular Clusters: Infrared Luminosity Functions*; 4 nights (10-13 May 2000).

52. TNG: PI: Gratton, R.G., CoIs: Carretta, E., **Fusi Pecci, F.**, **Clementini, G.**; *The location of the main sequence of M92, one of the most metal poor Galactic Globular Clusters*; 3 nights (11-13/06/1999).

53. TNG: PI: **Clementini, G.**, CoIs: **Cacciari, C.**, **Fusi Pecci, F.**, Di Fabrizio, L.; *JK photometry of RR Lyrae variables in M3 and NGC5466*; 4 nights (14-17/05/2000).

54. TNG + OIG: PI : Fontana, CoIs: Cimatti, **Pozzetti, L.**, Daddi, **Ciliegi, P.**, **Gruppioni, C.**, **Zamorani, G.**, Hasinger; *Toward the TNG Deep Field: a pilot study*; 3 nights (4-6/03/2000).

55. TNG–OIG: PI: Focardi, P., CoIs: Palumbo, G., **Zitelli, V.**, Bonoli, C.; *Tidal dwarf in interactive systems*; 2 nights, (Mar 1999)

Loiano

56. LOIANO–1.52m: PI: **Clementini, G.**, CoIs: **Tosi, M.**, **Merighi, R.**, **Bragaglia, A.**, Di Fabrizio, L.; *Fotometria CCD di RR Lyrae "anomale"*; 16 nights (10-14/02/1999, 20-26/03/1999, 6-9/04/1999).

57. LOIANO–1.52m: PI: **Clementini, G.**, CoIs: **Tosi, M.**, **Merighi, R.**, **Bragaglia, A.**, Di Fabrizio, L.; *Fotometria CCD di RR Lyrae "anomale"*; 19 nights (3-8/03/2000, 28/03-3/04/2000, 25-30/04/2000).

Miscellaneous

58. McDonald–2.7m: PI: Sneden, C., CoIs: **Clementini, G.**, Di Fabrizio, L., **Bragaglia, A.**, Gratton, R.G., Carretta, E., Ivans, I.I.; *High resolution spectroscopy of "anomalous" RR Lyrae variables*; 5 nights (10-14/02/1999).

59. AZT-24–1.2m Campo Imperatore: - Key program, PI: Caputo, F., CoIs: Bono, G., **Cacciari, C.**, Cassisi, S., Castellani, M., Castellani, V., **Clementini, G.**, Corsi, C.E., Degl'Innocenti, S., Di Fabrizio, L., Di Paola, A., Lbouchak, H., Marconi, M., Musella, I., Ortolani, S., Piersimoni, A.M., Piotto, G.P., Raimondo, G., Ripepi, V., Santolamazza, P., Speziali, R., Testa, V., Zoccali, M.; *Evolutionary and pulsation properties of Radial Variables*; 10 nights (3 in 22-24/05/2000).

BeppoSAX

60. BeppoSAX: PI: **Bardelli, S.**, CoIs: **Zucca, E.**, **Zamorani, G.**et al.; *Thermal-chemical-shock structure in supercluster*; 250.000 seconds (Jan 2000).

61. BeppoSAX: PI: **Bardelli, S.**, CoIs: **Zucca, E.**, **Zamorani, G.**et al.; *Spectroscopy of Merging Clusters*; 50.000 seconds (Jan 1999).

62. BeppoSAX: PI: **Comastri, A.**, CoIs: Vignali, C., Brandt, W.N., Leighly, K.M., Fiore, F., Guainazzi, M., Matt, M., Stirpe, G.M., Nicastro, F., Siemiginowska, A., Molendi, S.; *Ultra–soft variable Narrow Line Seyfert 1 Galaxies*; 70.000 seconds (Jan 2000).

XMM–Newton

63. XMM–Newton: PI: Ettori, S., CoIs: **Bardelli, S.**, **Zucca, E.**et al.; *Spatially resolved spectroscopy of merging clusters in the Shapley Concentration* ; 45.000 seconds (2000).

64. XMM–Newton: PI: **Comastri, A.**, CoIs: Vignali, C., Fiore, F., Antonelli, L.A., Cimatti, A., Daddi, E., Roettgering, H.J., Andreani, P.; *Searching for dust obscured AGNs in extremely red objects*; 50.000 seconds (TBD).

65. XMM–Newton: PI: **Comastri, A.**, CoIs: Vignali, C., Fiore, F., Cappi, M., Palumbo, G.G.C., Costantini, E., Laor, A., Mineo, T.; *X-ray spectroscopy at the "quasar era"*; 35.000 seconds (TBD).

66. XMM–Newton: PI: Brandt, W.N., CoIs: **Comastri, A.**, Gallagher, S.C., Boller, T., Chartas, G., Sambruna, R.M.; *XMM Spectroscopy of the X-ray detected broad absorption line QSO CSO 755*; 50.000 seconds (TBD).

67. XMM–Newton: PI: Brunetti, G., CoIs: **Comastri, A.**, Setti, G.; *Searching for inverse Compton emission in strong FRII Radio Galaxies*; 50.000 seconds (TBD).

68. XMM–Newton: PI: Fiore, F., CoIs: **Comastri, A.**, Vignali, C., Giommi, P., La Franca, F., Matt, G., Antonelli, L.A., Capalbi, M., Maiolino, R., Molendi, S., Perola, G.C., Perri, M.; *Chasing quasar 2 with XMM*; 85.000 seconds (TBD).

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

- **Comastri, A.**:
  - ESA: panel *Galaxies, AGNs, QSOs and BL Lacs* for the XMM time allocation (1999), member
  - ESA: Astrophysics working group (XAWG) for the XEUS mission, member

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

- **Marano, B.**:
  - CRA: member
  - CNAA: member of the Board and of the executive committee
  - LBT Scientific Advisory Committee: Chairperson
  - Bologna Astronomical Observatory: director and member of the Board

- **Sancisi, R.**:
  - ESO Scientific Technical Committee: member

- **Stanghellini, L.**:
  - Science Program Selection Office of STScI: member
  - Science Recruitment Committee of STScI: member

- **Tosi, M.**:
  - Working group *Local Late Galactic Evolution* at the International Space Science Institute (ESA) of Berna: member
  - ESO: Observing Programmes Committee (OPC) *Nearby Normal Galaxies*, member
  - Working group for the NASA mission *Interstellar Pathfinder*, member

- **Zamorani, G.**:
  - ESO: VIRMOS Science Team (approved instrument for VLT): member
  - ESA: panel "Surveys" for the XMM time allocation (1999): chairman
  - ST-ECF: ST-ECF Users Committee (1998 - 2000): member
  - SAX : Science Steering Committee (1999 - 2000): member
  - Bologna Astronomical Observatory: member of the Board
  - Arcetri Astrophysical Observatory : member of the Board

12 Organization of Workshops and Schools

Stellar populations as cosmic clock — From Far Infrared to Millimetre, National School of Astrophysics held at Carloforte (Isola di San Pietro, Italy), June 7–12

The European Large Area ISO Survey (ELAIS), Meeting of the European Network ELAIS held at Osservatorio Astronomico di Bologna, October 26 – 27

13 PhD theses at the Bologna Observatory

1. **Emiliano Diolaiti**, *Methods for adaptive optics data analysis*, in progress (**Parmeggiani, G.** and Bendinelli O. advisors)

2. **Filippo Fraternali**, *The gaseous halo of the spiral galaxy NGC2403*, in progress (**Sancisi, R.** advisor)

3. **Andrea Possenti**, *Evolution of binary systems and population synthesis of millisecond and sub-millisecond pulsar*, completed (**D'Amico, N.** advisor)

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

5. **Cristian Vignali**, *The HELLAS Survey: probing the multi-wavelength properties of the sources making the hard X-ray background*, in progress (**Comastri, A.** and Palumbo G. advisors)

14 Post-Doctoral and Post-Laurea fellowship

1. **Carlotta Gruppioni** CNAA Post-Doctoral fellow, completed

2. **Luca Di Fabrizio** Post Laurea fellow, in progress

3. **Maria Messineo** Post Laurea fellow, completed