Osservatorio Astronomico
di Bologna

Annual Report 2000

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Cover: Three-colours (B,V,I) composite image of the central part of ω Centauri, obtained with the Wide Field Imager (WFI) on the 2.2m ESO-MPI Telescope at La Silla as part of a programme devoted to Large Population Studies in Massive Globular Clusters (PI: F.R.Ferraro)

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 *Università di Bologna, Dipartimento di Astronomia* and with the *Consiglio Nazionale delle Ricerche (CNR).* Moreover, a large fraction of the staff is involved in international long term projects (VIRMOS, ISO-ELAIS, ESO slice project, K20 redshift survey).

This report has been prepared by **Angela Bragaglia**, **Lucia Pozzetti**, and **Paolo Ciliegi**, with the collaboration of Luca Ciotti, Antonio De Blasi, Hans De Ruiter, Marco Lolli, Monica Marra, Roberto Merighi and Valentina Zitelli.

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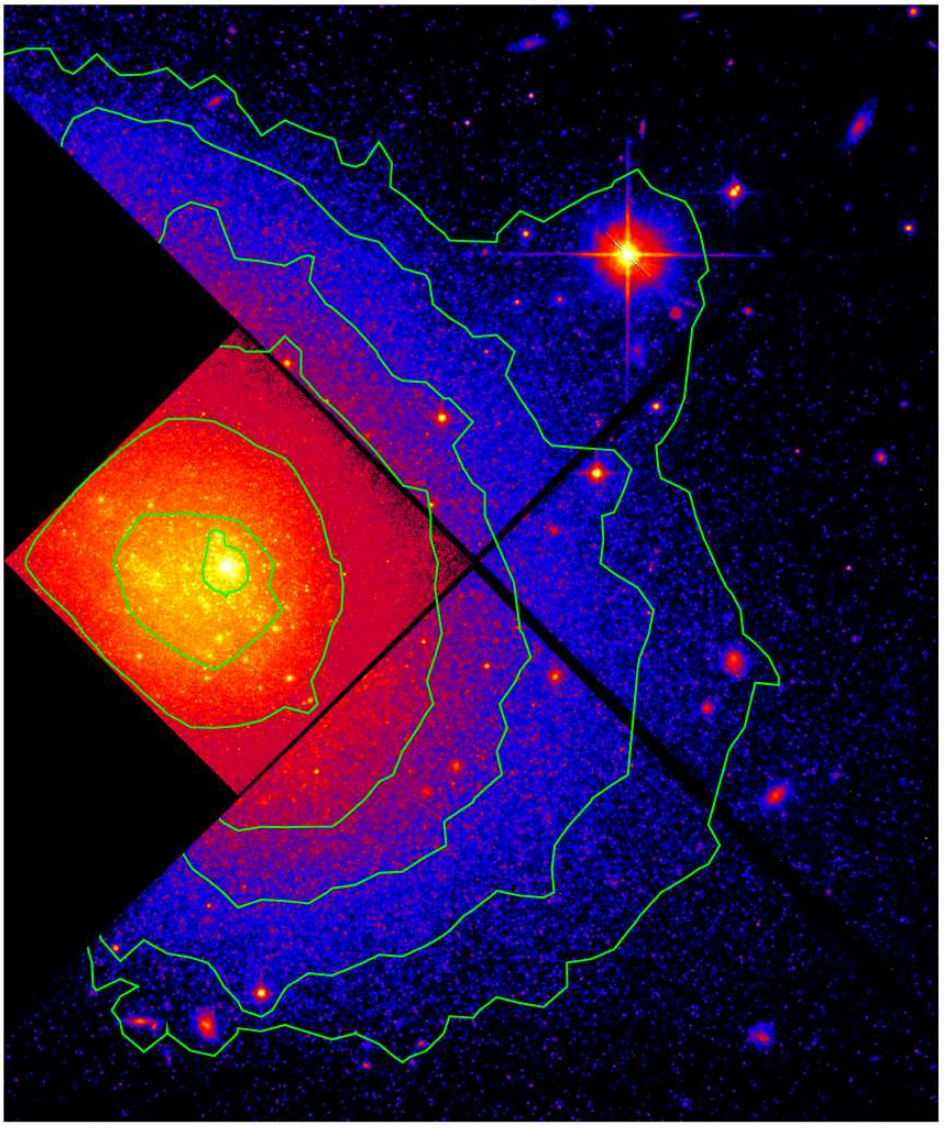
1 Stars and Stellar Populations



The Blue Compact Galaxy NGC 1705 observed with the Hubble Space Telescope. These WFPC2 data were obtained by Tosi, Aloisi, Clampin, Greggio, Leitherer and Nota to study the star formation history in this post-starburst system. The image presentation has been performed by Montegriffo. HST-Nicmos data of the same galaxy were also acquired by Tosi, Aloisi, Clampin, Greggio, Leitherer, Nota and Origlia.

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, S. Galleti, A. Possenti.

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

The present short description of the activity in the year 2000 has been organized in a few main sections to provide a very general overview: 1. The chemical evolution of the Galaxy, 2. Globular clusters, 3. Nearby Galaxies, 4. RR Lyrae Variable stars, 5. Eclipsing binaries, 6. Planetary Nebulae, 7. Pulsars, 8. 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 2000, we have proceeded in the effort of accurately analyzing the feedback between stellar nucleosynthesis and chemical evolution (Tosi 2000a), the evolution of the abundance gradients and the impact of Galactic chemical evolution models on cosmology. To this aim new models for D, ^{3}He, ^{4}He, ^{12}C, ^{13}C, ^{14}N, ^{16}O, ^{17}O, ^{18}O, ^{20}Ne, ^{22}Ne have been computed and compared with the available data, adopting all the most recent and reliable stellar yields.

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 emphasized by the Maxima and BOOMERANG experiments on the cosmic microwave background. Our group, in collaboration with Steigman (Ohio State Un.), Galli and Palla (OAA), has been particularly active in this field and has been the first in reaching these results (Tosi 2000b). Proposals of our group for data acquisition with the HST and the ESO-VLT have been approved and will allow to obtain new and stricter constraints on the still puzzling evolution ^3He. The observations are scheduled for early 2001.

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 light elements. This group has 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.

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

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

Open clusters (OC's) are 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. 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 less than 20 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 seven OC's with ages from 0.1 to 7 Gyr, and are presently working on IC1311, NGC4815, Be29 and Be17. We have also acquired photometric data for 10 more OC's using various telescopes (Dutch, Danish, and NTT in La Silla; Loiano; TNG). During 2000, we have completed the data analysis of Pismis2 and Be22, two old clusters poorly studied in the past.

High resolution spectroscopic data were acquired in 2000 with FEROS (1.5m, La Silla) for NGC2506, Cr261, IC4651, and NGC6134 (and preliminary results on their metallicity is found in Bragaglia et al. 2001b). Other spectra were acquired during the commissioning of SARG on the TNG for the two OC's NGC6819 ([Fe/H]=+0.09, Bragaglia et al. 2001, AJ, 121, 327) and NGC 6791 (work in progress).

1.1.3 Field blue Horizontal Branch (BHB) stars as tracers of the galactic halo

Involved people at OAB: Bragaglia, Cacciari.

The field BHB stars, along with the RR Lyrae variables and the carbon stars, are excellent tracers of the galactic halo stellar popula-

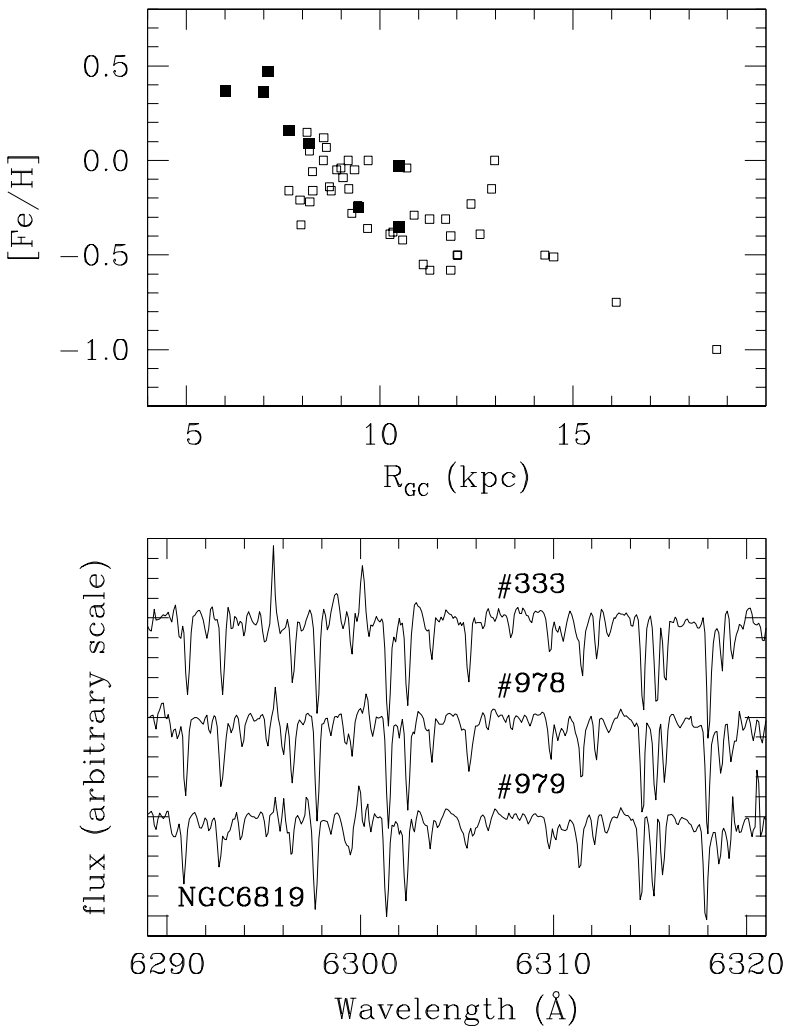


Figure 1: Upper panel: run of metallicity with Galactocentric distance for old open clusters. Filled symbols represent measures obtained with high resolution spectroscopy by our group. Lower panel: example of the spectra obtained with SARG on the TNG for three clump stars in the open cluster NGC6819; here we show the region near the OI 6300Å line.

tion. A detailed knowledge of their chemical and dynamical characteristics, therefore, is essential to understand whether the Galaxy formed by a monolithic collapse or in a hierarchical accretion/merging process.

A first problem our group was interested in, in collaboration with Kinman (NOAO) and Castelli (OATs), was the definition of the *local* halo characteristics using BHB stars in the solar neighborhood brighter than V = 11, i.e. nearer than about 1.2 kpc. Various types of observational data were collected and analyzed in order to select a pure sample of true BHB stars and eliminate the contamination from A-type stars belonging to the disk population: particularly important were high-resolution spectra to derive accurate elemental abundances, as well as radial and rotation velocities. We were thus able to isolate about 30 BHB stars (Kinman et al. 2000). Further dynamical studies will compare their galactic orbits with those of other nearby halo stars.

The questions of whether the high galactic halo is in retrograde rotation and how the velocity dispersion and flattening of the halo vary with height above the galactic plane are still controversial. They could be settled by studying halo stars nearer than about 10 kpc. In collaboration with Kinman, Buzzoni (TNG) and Chavez (Mexico) we are studying a sample of about 150 BHB and RR Lyrae stars near the North Galactic Pole, in the magnitude range from V=11 to 16, by means of radial velocities and GSC2 proper motions. Spectroscopic observations at the TNG are planned for spring 2001.

1.2 Globular Clusters

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

Indeed, globular star clusters are a key class of 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 theoretical stellar models, (2) Dynamics and stellar evolution, and (3) Cosmological applications. In addition to these main programmes, a new large project is aimed at the reconstruction of the formation history of the peculiar globular ω Cen.

In order to testify the high scientific impact of the research carried out in this Sector by the OAB group, it is relevant to note that in the last four years some of our papers (Ferraro et al. 1997, A&A, 324, 915; Ferraro et al. 1998, ApJ, 500, 311; Ferraro et al. 1999, ApJ, 522, 983; Pancino et al. 2000, ApJ, 534, L83) have been quoted in the annual review *"Astrophysics in ..."*, by Virginia Trimble, which summarizes the most important astrophysical discoveries of the year.

1.2.1 Tests of theoretical stellar models

Involved people at OAB: Ferraro, Fusi Pecci, 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 CMDs, from the MS Turn Off (TO) up to the termination of the Asymptotic Giant Branch (AGB), has been recognized to be the most powerful instrument for testing stellar evolutionary models (in particular the accuracy of the input physics, the reliability of canonical assumptions, etc.).

A fully fruitful test requires that the observations be a) *complete*, b) *statistically significant*, and c) *accurate and adequate* for each specific evolutionary sequence. Point (a) means that virtually all the stars in a given area of the cluster are measured down to a given magnitude level, and that reliable corrections for incompleteness can be applied below that level. Point (b) means that observations should cover most of the cluster extension. Point (c) requires e.g. 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 Paltrinieri (Univ. Roma) and Rood (Univ. 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) ob-

servations 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: we have constructed, using photographic and CCD photometry, and HST data, the most complete CMD in a Galactic GC, covering the entire cluster from the very center to a radial distance of about 6 arcmin. This huge work has been the subject of seven papers, in the last of which [Rood et al. (1999, ApJ, 523, 752)] we have presented the global LF for RGB-SGB-MS, showing a substantial agreement of the data with standard theoretical models. Such a data set has been also obtained for other clusters with different structural parameters and metallicity (M92, NGC2808, NGC288).

The potential use of such a database 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 (e.g. the Horizontal Branch) has been addressed mainly using UV–HST observations. A large data set has been secured during HST Cycles 4-5-6-9 and the first set of data analyzed has produced a variety of interesting results.

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 has been secured with SOFI at NTT and ARNICA/NICS at TNG. In total we obtained J,K images of a sample of $\sim$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)], showing an excellent overall agreement between the observations and the most updated theoretical models.

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

1.2.2 Dynamics and stellar evolution

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

Many new results are now supporting the claim that dynamical evolution of GGCs can affect their stellar populations. Schematically,

both the integrated cluster colors and the properties of individual objects confirm the existence of dynamically induced variations in the evolution of many cluster members.

In this scenario, we have started a long term project which aims at using GGCs as a laboratory to study the impact of the (internal) 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 HST observations we obtained for this project allowed us to collect a homogeneous data-base for 8 GGCs, and 5 more are being observed during cycle 9. The analyzed data in 4 GGCs showed important results, e.g. the discovery of the spectacular population of Blue Stragglers (BSS) in M80.

   The discovery of UV objects lying in the vicinity of LLGCX sources [Ferraro et al. (2000, ApJ 537, 312)] and/or Hα-excess stars [Ferraro et al. (2000, ApJ, 542, L29)] suggests that these stars might be a new sub-class of cataclysmic variables, produced by stellar interactions in a dense core. Similar objects, with strong UV emission, have been also found in NGC288 [Bellazzini & Messineo (2000)]; for these stars a VLT-FORS2 spectroscopic follow-up has been obtained. A method for deriving the fraction of binary systems in GGCs from the secondary main sequence in CMD is also under development.

   In addition, 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 20 hours of ROSAT observing time have been allocated to this program and preliminary results on the detection of a LLGCX in NGC288 have already been published. This part of the research is in collaboration with Rood and Sarazin (Univ. Virginia), and Paltrinieri (Univ. Roma).

2. The LF of stars below the MS TO is a powerful tool to study the modifications of the Present Mass Function (PMF) 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

PMF. Both the cluster internal dynamics and the tidal interaction with the Milky Way significantly contribute to modify the PMF. Our research is now concentrating on finding clear evidence 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: 3 GGCs, namely NGC6218, NGC6838, and NGC6712, have been observed.

We have fully analyzed the NGC6712 data, and we have found the *first evidence of a disrupting globular cluster*. NGC6712 is a low-concentration, intermediate-high metallicity GC with some peculiar characteristics. First, it is the lowest density GC containing a low mass X-ray binary, and since LMXB's are thought to form via tidal capture in high density clusters, its presence in the core of a loose cluster is somewhat surprising. Second, it appears to be experiencing a severe interaction with the Galaxy due to its orbit which gives rise to several passages through disk and bulge.

Our VLT observations of NGC6712 showed the effect on the cluster stellar population of a severe interaction with the disk and the bulge of the Galaxy:

(a) We provided the first unambiguous evidence that this cluster has an *inverted* mass function, since the MS Luminosity Function (hence the global Mass Function) sensibly drops below the TO (Andreuzzi et al. 2001, A&A, in press). NGC6712 is the only GGCs known so far for which this effect has been detected. As suggested by its orbit, and supported by N-body simulations, this is probably due to a severe depletion of low mass stars in the MS luminosity function, probably stripped away by the tidal force of the Galaxy.

(b) The extensive multi band (UBVR) photometry we carried out added additional support to this scenario. We discovered the presence of a UV, Hα-excess star located a few arcsec away from the optical counterpart to the LMXB; this object is an additional promising interacting binary candidate, suggesting that strong stellar interactions might have occurred at some remote stage of the cluster evolution (Ferraro et al. 2000, ApJ, 542, L29). The study of the evolved stellar population in the cluster (Paltrinieri et al. 2001, AJ, in press) revealed a surprisingly

large population of BSS when compared with clusters of similar mass and central concentration. Furthermore, we discovered a luminous UV-bright object in the core, whose position in the CMD closely matches that of a star evolving in the post-AGB phase. A second object with similar characteristics has been located further out in the cluster at $\sim 4'.4$ from the center.

The presence of a LMXB, our discovery of an additional promising interacting binary candidate and the large BSS population, provide additional support to the fact that star collisions might have occurred in the past: at that time, NGC6712 probably was a massive and concentrated cluster and collisional BSS (and other exotic objects such as interacting binaries) formed copiously via dynamical collisions. Later, these stars have migrated towards the center because of mass segregation, where we now see them. The continued action of tidal stripping and disk shocking has removed most of the cluster mass, driving it towards dissolution. What we now observe is nothing but the remnant core of a disrupting cluster and its population of peculiar objects, which are otherwise totally unexpected for its actual mass.

This research has been carried out in collaboration with Paresce (ESO), De Marchi (STScI), Andreuzzi, Buonanno and Pulone (OAR), and Paltrinieri (Univ. Roma).

1.2.3 Cosmological applications

Globular Clusters are the fossils of the remote Galaxy formation epoch, thus they can provide meaningful constraints to a few fundamental quantities (like for example the primordial helium abundance, and the distance scale, hence the age scale of the Universe) of primary cosmological impact. The OAB projects in this field are shortly described below.

- **The time scale of the formation of globulars in the Milky Way: a differential age test**
  Involved people at OAB: Bellazzini, Ferraro, Fusi Pecci, Galleti.

  The measure of age differences between galactic globulars is a powerful tool to reconstruct the earliest phases of the formation of the Milky Way. We have performed a specific test to estimate

the age difference between two very important clusters, NGC 288 and NGC 362, that have very similar chemical composition but very different Horizontal Branch morphology. We applied a refined version of the so called *bridge test* (Stetson, Vandenberg & Bolte 1996) that makes use of a cluster with bimodal HB morphology, in the present case NGC 1851, to match the otherwise incompatible HBs of NGC 288 and NGC 362. Adopting the above technique on a very homogeneous database we provided a very robust estimate of $\Delta^{age}_{N288-N362} = 2.0 \pm 1$ Gyr, independent of distance and reddening and supported by recent detailed abundance analysis. It is interesting to note that though NGC 362 formed a couple of Gyr later than NGC 288, both clusters have α elements abundances enhanced by the same amount with respect to the Sun. This indicates that the two clusters were born in former galactic sub-units that had an independent star formation history and chemical evolution.

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

  The data-base presented in Ferraro et al. (1999) 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 is being carried out in collaboration with Limongi (OAR), Straniero (OATe), and Chieffi (CNR, Roma).

- **Distances and ages of Galactic globular clusters**

  The problem of a better determination of the age of GGCs is strictly connected with a better determination of their distance. Once distances are known, ages follow from the absolute magnitude of the TO which is the "stellar clock" for dating the clusters. Different standard candles can be used in order to derive the distance to GGCs. Here we list some of the method adopted by different groups at the OAB:

  (I) The white dwarf cooling sequence
  Involved people at OAB: Bragaglia, Ferraro.

The principal source of uncertainty of the absolute age of GGCs is mainly due to the large uncertainty (± 0.25 mag, for the pre-Hipparcos era) in measuring the distance modulus of these objects. OAB researchers are collaborating to an HST project (a total of ~ 50 orbits have been allocated) which uses a new standard candle, the *White Dwarf cooling sequence*, in order to determine the distance to a sample of GGCs. A first result has been published in Renzini et al. (1996): for *the very fist time* the distance to NGC 6752 was measured with an uncertainty of only 0.1 mag. This result showed that there is the possibility to derive the age of GGCs, hence a significant lower limit to the age of the Universe, with an accuracy better than 1 Gyr.

We are now extending this study to other nearby GGCs: recently the procedure was applied to 47 Tuc and a distance modulus of $(m-M)_V = 13.27 \pm 0.14$ and an age of 13 ± 2 Gyr were derived (Zoccali et al. 2001, ApJ, in press).

(II) The main sequence fitting technique
Involved people at OAB: Bragaglia, Clementini, Fusi Pecci.

One of the simplest and most robust technique for deriving distances to GCs is the Main Sequence Fitting technique: the GC Main Sequence is compared to a suitable "template" formed by metal-poor subdwarfs in the solar neighborhood, whose distances are accurately measured via trigonometric parallaxes.

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 ± 0.25mag, and large errorbars on ages (± 4 Gyr). With the release of the 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, 1998; Pont

et al. 1998; Gratton et al. 1997). 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.

(a) In collaboration with Carretta and Gratton (OAPd), 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. 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.

(b) Besides parallaxes, a number of different ingredients and assumptions enter into the MSF technique, which all contribute to its present accuracy ($\pm$0.12 mag). The major contribution arises from possible systematic errors (at about 0.1 and 0.02 mag level, respectively) in the reddening and metallicity scales adopted for the field subdwarfs and the GC stars, with errorbars of $\sim$ 0.07 mag from each source. An ESO Large Programme (PI Gratton) is trying to cut the uncertainty affecting the MSF distances down to $\pm$0.07 mag (i.e., an uncertainty dominated by the parallax error) and the corresponding errors in the GC ages to $\pm$1 Gyr, by addressing these effects. In 2000, we obtained high resolution spectra (R$\geq$ 40000, with UVES at VLT2, 12 nights in total) of

a large number of stars at the main sequence turn-off and at the base of the sub-giant branch of NGC6752 and NGC6397, and another 6 nights have been allocated to extend the spectroscopic analysis to NGC104, and to the two very metal poor clusters NGC 6809 and NGC 7099. The abundance analysis of the NGC6752 and NGC6397 stellar spectra has demonstrated that in both clusters the [Fe/H]'s obtained for the TO-stars agree perfectly (within a few per cents) with that obtained for stars at the base of the RGB (Gratton et al. 2001, A&A, in press, and ESO Press Release 03/01), thus removing one of the possible major sources of uncertainty claimed to affect the MSF distances.

This part of the project is conducted in collaboration with Bonifacio, Centurion and Molaro (OATs), Carretta, Claudi, Desidera, Gratton and Lucatello (OAPd), Castellani (Univ. Pisa), Chieffi (CNR, Roma), D'Antona (OAR), Francois and Pasquini (ESO), Grundhal (DAO), Sneden (Univ. Texas), Spite (Meudon), and Straniero (OATe).

(III) The theoretical ZAHB level
Involved people at OAB: Ferraro, Fusi Pecci.

The large database published in Ferraro et al. (1999) has allowed us 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 clusters in the low-metallicity domain. Also other features in the CMD of GGCs, like the RGB-bump and the AGB-bump can be safely used as standard candles. This part of the research has been carried out in collaboration with Limongi (OAR), Straniero (OATe), and Chieffi (CNR, Roma).

High quality V and I HST data have been obtained, analyzed, and will soon be 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 to accurately date this GGC and set a lower limit to the age of the Galaxy formation epoch. This part of the research has been carried out in collaboration with Rood (Univ. Virginia), Buonanno and Andreuzzi (OAR).

1.2.4 ω Cen: a cornerstone in the evolution of stellar systems

Involved people at OAB: Bellazzini, Ferraro.

The very peculiar nature of ω Centauri is known since long time, but a convincing interpretation of its many anomalous properties is still missing. It is the most massive GGC, and the *only* one which shows clear and undisputed variations in the chemical content of its stars. From this point of view, ω Cen could be considered a "bridge" system between the genuine globulars, which are unable to retain the gas ejected by their former massive stars, and the dwarf galaxies, which are the least massive self-enriching stellar systems known. It is interesting to note that those dwarf spheroidal satellites of the Milky Way that are less luminous than ω Cen (e.g., UMi, Draco and Carina) show very modest abundance spreads with respect to this cluster.

Due to its peculiar characteristics, ω Cen represents a cornerstone in the evolution of stellar systems. For this reason we have started, in collaboration with Pancino (Univ. BO), a long-term project specifically aimed at performing a detailed photometric and spectroscopic study of the stellar population in ω Cen, which is going to become one of the major project of the OAB stellar group, coordinating a large international collaboration.

The first data set acquired at the ESO 2.2m with WFI has revealed a new anomalous population: a distinct narrow RGB, previously unknown, significantly redder than the bulk of the normal RGB stars (RGB-a, see Fig.2; Pancino et al. 2000, ApJ, 534, L83).[1]

Some stars in our CMD have been analyzed by previous spectroscopic studies (see figure), but only six of the RGB-a stars had previous spectroscopic determinations. Our preliminary photometric analysis suggests that:

(a) The RGB-a is a real feature of ω Cen : all of the stars coidentified in the N96 sample are clear members, with radial velocities very similar to that of the whole cluster. The anomalous population constitutes $\sim 5\%$ of the whole stellar content of ω Cen.

(b) The anomalous population is very metal rich, thus we have probably isolated a sub-population enriched by a previous generation of intermediate mass stars. The sharp and clear-cut shape of the

[1]This paper was quoted by V. Trimble as one of the most relevant astrophysical result in 2000

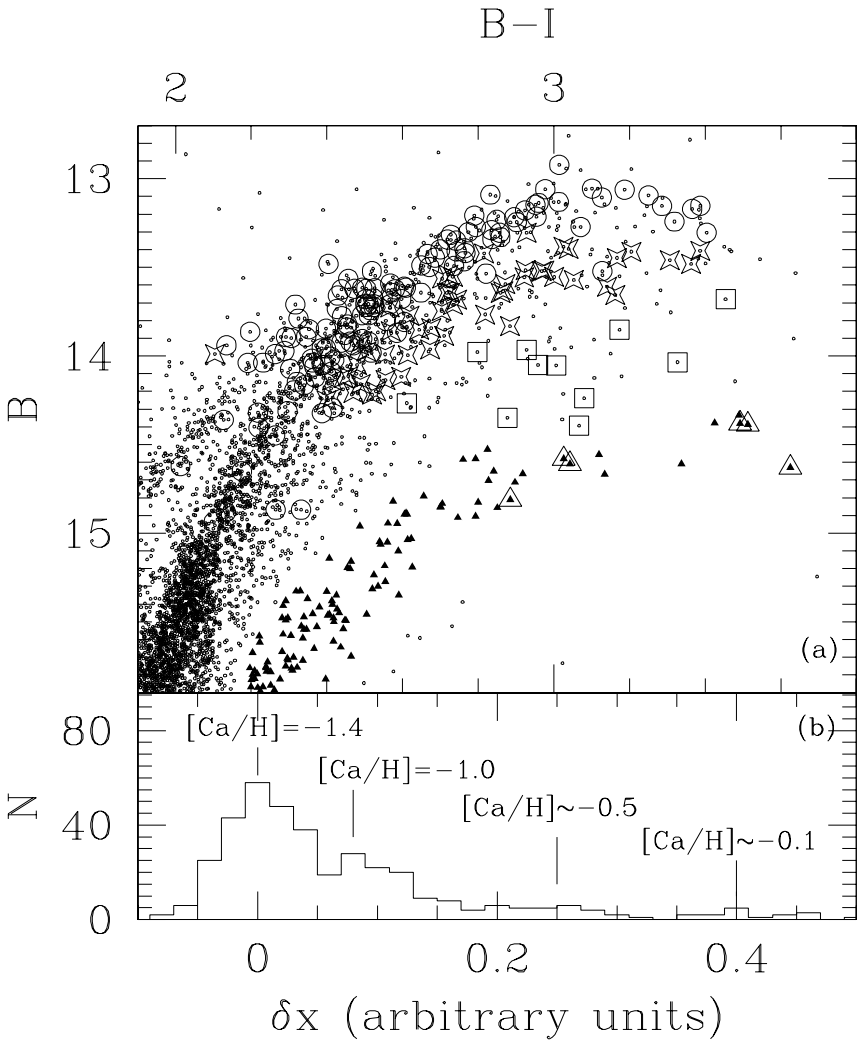


Figure 2: *(a):* CMD of the upper RGB region of ω Cen. Stars in the RGB-a have been plotted as *small filled triangles*, while large empty symbols indicate stars with known metallicity (*large open circles* for $-1.5 < [Ca/H] < -1.3$, *large open stars* for $-1.1 < [Ca/H] < -0.85$, *large open squares* for $-0.65 < [Ca/H] < -0.4$, *large open triangles* for $[Ca/H] > -0.3$). *(b):* Histogram of the distribution of the distances from the mean ridge line of the Metal Poor population.

RGB-a in our CMD allows us to select a representative sample of stars along the whole RGB-a sequence and to measure with high resolution spectroscopy the detailed abundance pattern of each of them.

(c) Significant features are present below the principal Sub Giant Branch (SGB), confirming the existence of different populations within ω Cen and suggesting a possible age spread among them. Unfortunately, these observations do not have the resolution to provide a sufficient insight into the TO region.

We are now coordinating a large national and international collaboration to conduct photometric and spectroscopic observations aimed at finally solve the mistery of the stellar content of this surprising cluster. To do so, we are using the astronomical instrumentation available at ESO, on board of HST and in other international telescopes.

The spectroscopic part of the program comprises the following :
(1) High resolution ($R = 40000$) VLT-UVES spectra to derive the first accurate measures of Iron, Ca and α elements abundances along the RGB-a. Ten giants have already been obtained and twenty more (mostly on the RGB-a) are planned during spring 2001. This part of the research is performed in collaboration with Pasquini and Hill (ESO).
(2) Low and medium resolution complementary spectroscopy: i) in collaboration with Norris (Australia) for a comparable sample of giants [using the 2.3 m telescope at MSSSO (Australia)] in order to study the CH,CN molecular species, Ca, Fe and s-elements (Sr and Ba) abundances; and ii) in collaboration with Richtler and Hilker (ESO-Chile) for stars at the TO level [using FORS1 at VLT1].
(3) IR spectroscopy for the brightest cooler giants at the tip of the anomalous branch, already secured.

Furthermore, as member of the ITAL-FLAMES consortium, the OAB group has decided to spend part of the FLAMES GTO to perform a extensive spectroscopic survey of stellar populations in ω Cen (giants and HB stars).

In addition to this, the following extensive photometric campaigns are already ongoing or planned: (a) IR photometry using SOFI at NTT, (b) a multiband ($UBVI$) high resolution survey (at the VLT) to resolve the complex structure of the TO-SGB region and to assess the age of each sub-population [note that the combination of point (b) and the spectroscopic observations at the TO will enable us to correctly disentangle ages and metallicities of the TO sub-populations], (c) UV-photometry, in collaboration with Rood (Univ. Virginia), us-

ing the WFPC2 on board of HST in order to study the extreme hot HB population and other UV-excess objects; (d) an Hα/continuum survey, using the WFI at the 2.2m in collaboration with Augusteijn (IAC), in order to detect interacting binaries with anomalous Hα emission.

1.2.5 Optical and NIR imaging of Magellanic Cloud clusters.

Involved people at OAB: Ferraro, Origlia.

A large photometric data–set in the optical and near infrared of a sample of intermediate–age LMC clusters has been assembled in collaboration with Testa (OAR) and Maraston (Univ. Munich). These clusters are the ideal *templates* for studying the evolution of stellar populations in galaxies, with a crucial impact on cosmology.

This data–set will allow i) to empirically calibrate the epoch of the so–called AGB and RGB *phase–transitions* predicted by the models, and ii) 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 age.

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

1.2.6 The Globular Cluster System of the Andromeda galaxy

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

The OAB M31 team, in collaboration with scientists of other italian and foreign institutions, is studying the globular clusters in M31 and other galaxies of the Local Group using both photometry (from the UV to the IR bands) and spectroscopy. The scope of the program is to utilize the globular cluster systems to improve our knowledge on the mass, dynamics and chemical evolution of the parent galaxies, and as secondary distance indicators and stellar population templates.

The M31 cluster system is the largest sample of GC's found in the Local Group, sufficiently close to allow individual stellar observations, and little affected by reddening, at least for a large sub-set in the outer halo. Since the typical cluster size at the M31 distance is comparable to 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 fail 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.

Discovery 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) and a better knowledge of its radial distribution.

(a) In this framework, in collaboration with Meusinger (Tautenburg), Testa and 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 will be done analyzing deep photometry of a 9x9 sq.deg. field centered on M31 that will be taken at Campo Imperatore. The morphology of the candidates obtained via color selection will further be checked on digitized UBVR deep 2m Tautenburg Schmidt telescope plates covering the same field. Subsequent spectroscopic observations will decontaminate definitively the sample. The survey will allow to detect a significant fraction of faint candidates in the outer regions, that have never been detected so far.

(b) 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 CMD of globular clusters in external nearby galaxies. Our team is carrying out a long-term project based on observations with HST 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: i) to improve the accuracy of globular cluster distance and age determinations, via the accurate determination of the HB luminosity as a function of metallicity for a number of clusters in M31; ii) 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; and iii) 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 (UCLA) and coworkers] for 9 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 completed, preliminary results have been presented at international conferences, and the papers discussing the various characteristics of the clusters and nearby halo fields are in preparation. Finally, we are preparing a comprehensive, homogeneous revised catalog of all morphological, spectrophotometric, astrometric and kinematic data for the clusters and the clusters candidates in M31.

(c) As a bonus of the HST pointings which have M31 GC's as primary targets, we obtain a wide photometric survey sampling the disc and the halo of M31 toward 16 different lines of sight. A fully automated pipeline has been developed for the data reduction and a final sample of 470704 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.

1.2.7 Globular Cluster Systems in external galaxies

Involved people at OAB: Cacciari, Federici.

Spectroscopy of globular cluster systems is essential to investigate the existence of stellar sub-populations with different chemical and/or dynamical characteristics in a given galaxy, to estimate the galaxy mass and to probe the existence of a dark matter halo. 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 with FLAMES or VIRMOS, we have undertaken a wide-field multicolor imaging survey of galaxies as far as the Virgo cluster. Five galaxies of all morphological types have been observed in March 2000 using the WFI at the 2.2m telescope; the analysis of these data will lead to the selection by color and shape criteria of accurate samples of globular clusters candidates.

A similar analysis has been undertaken on the northern elliptical galaxies NGC4125, NGC5831 and NGC6173, whose characteristics suggest them to be the product of recent mergers, and there-

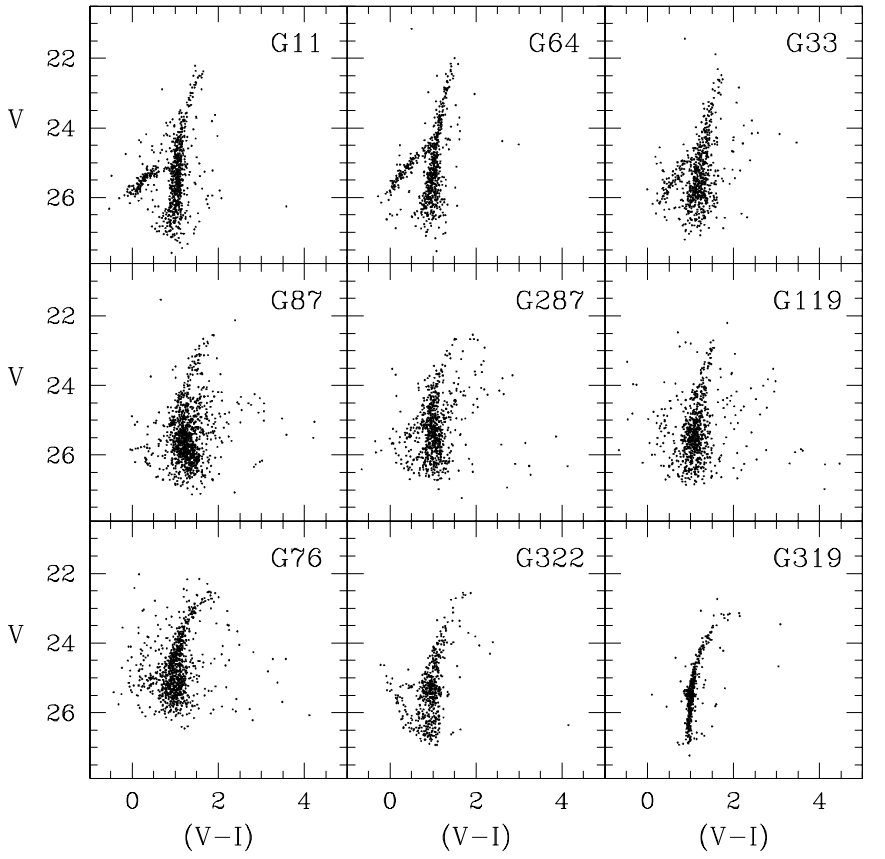


Figure 3: Color-Magnitude Diagrams obtained from Hubble Space Telescope WFPC2 observations of 9 M31 globular clusters.

fore 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 are in progress.

In a few galaxies where reasonably good samples of globular cluster candidates are known already, we have obtained spectroscopic data. In collaboration with Held (OAPd) and Testa (OAR) we are studying the globular cluster system of NGC5128 (Cen A), which is the closest gE galaxy, 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. Analysis of past data on 31 halo GC's, showed that i) the globular clusters of NGC5128 are on average more metal rich than those of our Galaxy, with no super metal-rich clusters; and ii) the metallicity distribution is bimodal, which points to a composite cluster population. To put these findings on a more solid statistical base and to address the question of a metallicity gradient in the GC system of Cen A, the study was extended to the inner regions and spectra of a sample of 45 confirmed clusters were taken with EMMI/MOS at NTT in 1998. These spectroscopic data, besides confirming the above result, also provide the means to identify and distinguish the various populations from their kinematics.

In the same framework, deep MOS spectroscopy of globular clusters in the Sombrero galaxy (NGC4594) has been obtained using FORS1 at the VLT. NGC4594 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 data are currently being analyzed.

1.3 Nearby Galaxies

1.3.1 Star formation histories in late–type dwarf galaxies

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

Late–type dwarf galaxies are playing an increasingly central rôle 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 counterpart 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 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 (dwarf irregulars, giant irregulars, and blue compact galaxies) (Tosi 2000, 2001).

(a) To this aim we are undertaking a long term project (in collaboration with Aloisi, Clampin, Leitherer and Nota, at STScI) to study, from deep and accurate photometric data (ESO-VLT and HST), the stellar populations of a number of dwarfs known to show evidence of galactic winds. 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) and amply tested and applied by the international community.

In 2000 we have completed (Aloisi et al. 2001) the analysis of the red stellar population in NGC1569, thanks to new HST-Nicmos data. We are now deriving its star formation history with the method of synthetic CMDs, combining this infrared information with our previous HST-WFPC2 data. Particular attention has been devoted (Origlia et al. 2001) to the three super-star-clusters hosted in this peculiar starburst galaxy, and to the other candidate young globular clusters, whose photometric (BVJH) and spectroscopic (with HST-FOS) properties have been examined to infer their ages. We have completed the analysis of the HST-WFPC2 and HST-Nicmos UBVIJH data on NGC1705 (Tosi et al. in preparation) and are studying now its star formation history. Then, numerical chemical evolution models will be computed for both NGC1569 and NGC1705, taking also into account the effects of the supernovae explosions on the hydrodynamics of their interstellar medium and the possible onset of galactic winds.

(b) Within the class of dwarf galaxies, the Blue Compact Dwarfs (BCDs) 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) 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 Schulte-Ladbeck and Drozdovsky (Univ. Pittsburg), Hopp (Univ. Munich) and Crone (Skidmore College) we are investigating in detail the stellar content of a sample of 5 BCD galaxies for which we have HST photometry proprietary data. Archival HST data are also being investigated to enlarge the sample of galaxies. By applying the synthetic 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 2000 we have completed the study of the infrared CMD of Mrk 178 (Schulte-Ladbeck et al. 2000) and of IZw36 (Schulte-Ladbeck et al. 2001); of the optical (V and I) CMD of UGCA290 (Crone et al. 2000) and of NGC6789 (Drozdovsky et al. 2001). In all of these cases a clearly developed RGB was detected, leading to a robust estimate of the distance to these galaxies. All these BCDs show evidence of conspicuous star formation at ages older than $\sim$ 2 Gyr, clearly ruling out the possibility that these objects are experiencing their first Star Formation episode. The analysis of the observed CMD through simulations suggests that the SF rate in the past occurred at a lower average rate than the younger episode, and that in the last 1 Gyr these galaxies formed stars at an approximately constant rate. We are presently carrying on more detailed investigations on this quantitative aspects. In addition, we are analyzing three more galaxies, to enlarge the sample of studied objects. 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.

1.3.2 Getting accurate distances to local-group galaxies from TRGB

Involved people at OAB: Bellazzini, Cacciari, Ferraro, Origlia.

The Local Group (LG) of Galaxies is a unique laboratory to study the properties of the most common types of galaxies in the Universe. Moreover it offers the opportunity to calibrate the luminosities of *standard candles* – such as Cepheids and RR Lyraes, see Section 4 – which can be used to determine the extragalactic distance scale, hence the value of H_0 and the age of the Universe. Thus, the determination of absolute distances of nearby galaxies plays a critical role in the determination of cosmological quantities. In the last decade a formidable observational effort has been devoted to derive distances to the Local Group galaxies by using *classical* high precision distance indicators (e.g. Cepheids variables – Madore & Freeman 1991, Shara et al. 1996, or RR-Lyraes and the luminosity of the HB – Shara et al. 1992, Caputo et al. 1995, Clementini et al. 2001), and by searching for new possible techniques, since it has become evident that distance determinations with independent techniques are crucial in order to reveal possible sources of systematic errors.

Among the relatively *new* techniques the so-called Tip of the Red Giant Branch (TRGB) method has received increasing credit in recent years. The TRGB marks the phase of helium ignition in the degenerate He core of low-mass stars (helium flash). According to theory, the luminosity of TRGB stars depends only on i) the He core mass, which is remarkably costant for ages larger than 2-3 Gyr, and ii) the metallicity. Moreover, the TRGB magnitude in the near-infrared (I,J,K) shows very little sensitivity to metallicity, and is therefore a fair standard candle.

Since this method has a huge potentiality and can be efficiently used to derive accurate distances, we have started a large programme (PI: Ferraro) using the new instrumentation available at the TNG (DOLORES+NICS, 3+3 nights assigned up to now) in a coordinated attempt to determine the distance scale in the Local-Group using the TRGB method, both through optical (V,I) and IR (J,K) magnitudes.

Moreover, we are also working to improve the observational basis of the TRGB calibration: in a recent paper (Bellazzini, Ferraro & Pancino, 2001, ApJ, submitted) we obtained an accurate estimate of the M_I^{TRGB} for the globular cluster ω Cen, using *(a)* the largest existing photometric database ever assembled for a globular, by Pancino et al. (2000, see Section 1.2.4), and *(b)* a direct distance estimate for ω Cen, recently obtained from a detached eclipsing binary. The derived value $M_I^{TRGB} = -4.04 \pm 0.12$ provides the most accurate empirical zero-point for the calibration of the M_I^{TRGB} vs. [Fe/H] relation, at

[Fe/H]~ -1.7. We also derived a new empirical M_I^{TRGB}–[Fe/H] relation, based on the large IR dataset of red giants in Galactic Globular Clusters recently presented by Ferraro et al. (2000). This database (extending up to [Fe/H]$=-0.2$) covers a more appropriate metallicity range, for extragalactic applications, than previous empirical calibrations. The proposed relation is in excellent agreement with the newly determined zero-point. This research has been carried out in collaboration with Pancino (Univ. Bologna).

1.3.3 The Sagittarius Dwarf Spheroidal

Involved people at OAB: Bellazzini, Ferraro.

Dwarf spheroidal galaxies (dSph's) 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's is of paramount importance to recover the past history of the Milky Way galaxy and to better understand the whole process of evolution and organization of matter in the Universe.

The Sagittarius (Sgr) dSph is the most prominent member of the family of dSph's orbiting the Milky Way both in luminosity and extension in the sky. Moreover, the Sgr is experiencing a process of disruption due to tidal interaction with the Galaxy.

Our group started a systematic study of stellar populations in the Sgr dSph producing the largest photometric survey: three wide (9×35 arcmin^2) fields have been observed at the NTT and the photometry of 90,000 stars has already been published in 1999.

Now we are planning to reduce part of the archive data acquired by EIS survey with the WFI at the 2.2m telescope, and as members of the ITAL-FLAMES consortium (in collaboration with OATs) we are planning to use part of the FLAMES GTO time in order to perform an extensive spectroscopic campaign of stellar populations in this disrupting galaxy. This research is beeing carried out in collaboration with Pancino (Univ. Bologna).

1.4 RR Lyrae variable stars

RR Lyrae's have long been recognized to be excellent tracers of old stellar populations, as well as primary distance indicators for Popu-

lation 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 primary distance indicators in the Galaxy and in the Magellanic Clouds, RR Lyrae stars are cornerstones 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 RGB to fall inside the instability strip of the HB, 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 HB.

RR Lyraes and their rôle in establishing the astronomical distance scale have been a major field of study at the OAB since 1984 (e.g. Cacciari et al. 1987). At present, a large number of research programs at various levels of completion are 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. New software tools have been developed, purposely designed to allow the identification of variable stars and to perform period searches and studies of multiple 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, and to make the developed tools platform-independent in order to make them available to the whole astronomical community.

1.4.1 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, and the luminosity level of the clump stars in the bar of the Large Magellanic Cloud and their rôle 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 ΔS metallicities have been derived for 6 double-mode (RRd) pulsators in the sample (average metallicity: [Fe/H]$=-1.5 \pm 0.2$). These metal abundances coupled with mass determinations from pulsational models purposely computed and the Petersen diagram are used to compare the mass-metallicity distribution of field and cluster variables. Field and cluster RRd's are found to follow the same mass-metallicity distribution, strengthening the case for uniformity of properties between field and cluster variables [Bragaglia et al. 2001b, AJ, in press]. The global pulsational properties of the sample as well as a very accurate estimate of the average apparent luminosity of the LMC RR Lyrae's and of the clump stars (drawn from a sample of more than 8000 LMC clump stars), have been obtained from the photometric data and compared with previous results in the literature, the OGLE data-base in particular. An independent estimate of the LMC reddening was obtained from the colors of the edges of the instability strip defined by the RR Lyrae in our sample.

BVI photometry in extremely good seeing and photometric conditions has been obtained at the 1.5 m Danish telescope at La Silla in January 2001. Reductions are in progress. These new data allow an extremely precise photometric calibration of the entire data set, a much robust assessment of our reddening determination, and a straightforward comparison with OGLE photometry for the LMC clump stars, with fundamental bearings upon the the *short* and *long*

distance scale controversy [Clementini et al. 2001, AJ, submitted - astro-ph/0004771]. Furthermore, the addition of the new data points will allow a much improved refinement of the light curves and of the derived periods and epochs of the RR Lyrae variables [Di Fabrizio et al. 2001, in preparation].

1.4.2 Applications of the Baade-Wesselink method

Involved people at OAB: Cacciari, Clementini.

The Baade-Wesselink determination of the absolute luminosity of the galactic field RR Lyrae variables is currently being revised in order to test the effects on this technique of the most recent model atmospheres with various approximations in the treatment of convection, different values of turbulent velocity and more complete and accurate opacity tables, as well as the use of the instantaneous gravity along the pulsation cycle (Cacciari et al. 2000, 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. 2001). Within this framework, we have started an observing program of a few RR Lyraes in the globular cluster M3 using IR (K-band) ARNICA data taken at the TNG. Along with accurate radial velocities (observations with SARG are scheduled in spring 2001), this database will be used to apply the B-W method directly on RR Lyraes in this very interesting globular cluster. The very few previous studies of this type, that date back to about 10 years ago, did not produce reliable results due to the poor quality of the data, obtained with smaller telescopes and less powerful detectors.

1.4.3 RR Lyrae in Local Group galaxies and in globulars

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

A search for RR Lyrae variables in Local Group Galaxies [Leo I, Phoenix, NGC6822 and other dwarf spheroidals, in collaboration with Held, Saviane, Momany and Rizzi (OAPd)] is being carried out,

as well as for variables in some M31 globular clusters.

(a) 40 V and 20 B frames of the Leo I galaxy have been obtained with WFI at the ESO 2.2m telescope in spring 2000. Data reduction has been completed, and a conspicuous population of RR Lyrae variables of both Bailey type *ab* and *c* has been successfully identified for the first time in this remote satellite of the Milky Way [Held et al. 2001, in preparation], thus adding further unambiguous evidence for the presence of old metal-poor stars in this galaxy and opening the possibility to derive an accurate distance to Leo I via these primary distance indicators. Light curves of some of the RR Lyrae's identified in Leo I are shown in Figure 4, along with their position on the color magnitude diagram. A more refined variable search will be performed on the WFI frames using the Optical Image Subtraction package ISIS2.1 (Alard 2000).

(b) A preliminary search for variables in 4 M31 GCs is taking place using HST archive data. If this feasibility test is successful, as it seems, the intent is to apply for future HST observing time for unambiguous identification and classification of these variables.

(c) A reanalysis of the properties of the RR Lyraes in the Sgr globular cluster M54 has been undertaken, using BVI photometric data obtained in 1999. The data reduction is completed and the analysis is in progress. Preliminary results include the clear identification of multiple stellar populations in the Sgr and the re-classification of M54 as intermediate in the Oosterhoff groups, thanks to the improved photometric quality of our data and the much larger number of variable stars that could be detected.

The search for RR Lyrae variables in metal-rich globular clusters is being extended to the clusters NGC6304 and Arp2.

1.4.4 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 (Univ. Texas), Marconi (OAN), Smith (MSU), and Wilhelm (Southwestern Un.)]. Continuated/adjacent photometric data have been obtained with the 1.52m

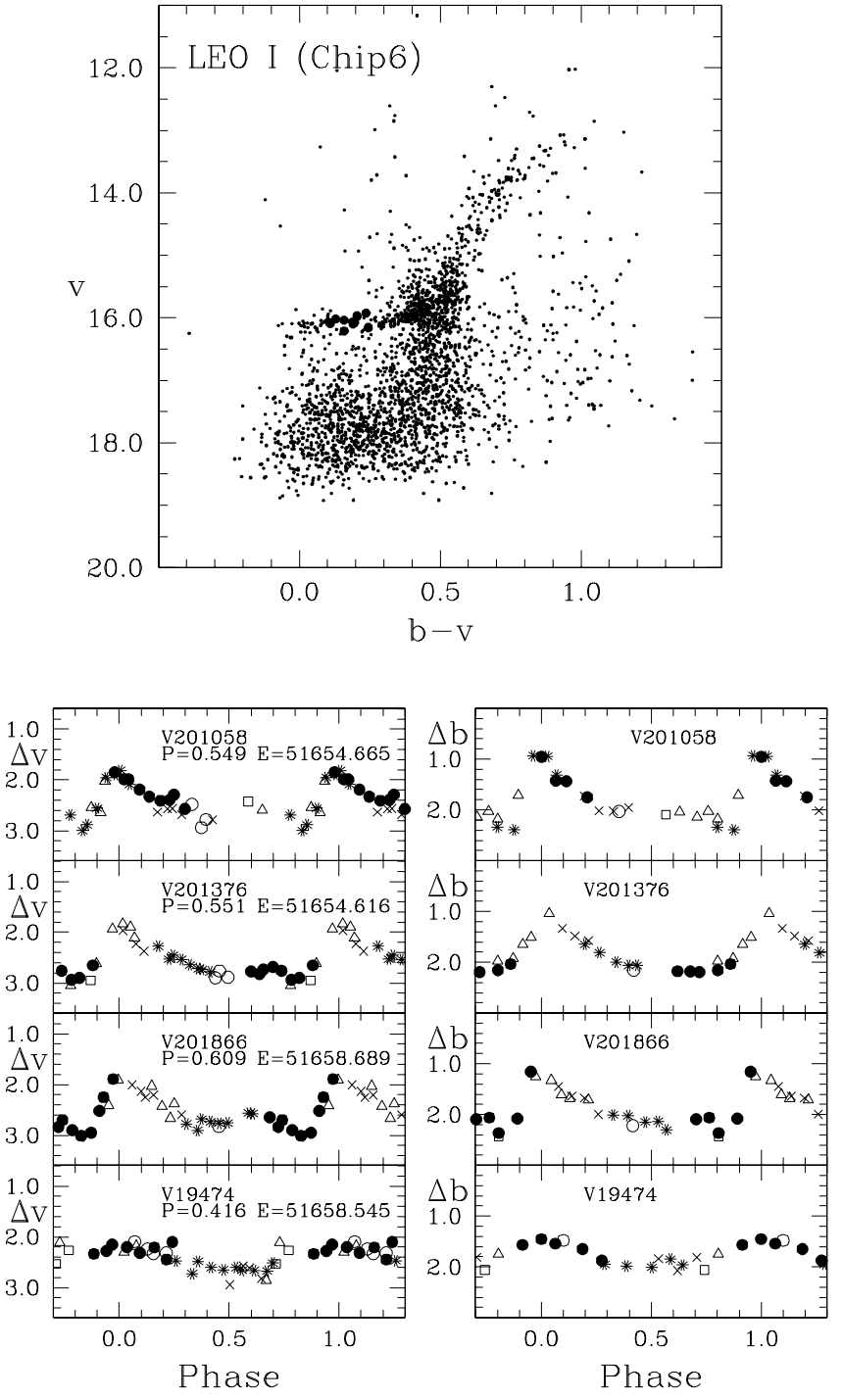


Figure 4: RR Lyraes variables identified for the first time in the dwarf spheroidal galaxy Leo I. Upper panel: uncalibrated HR diagram; lower panels: differential v and b light curves.

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. New photometric observations at the 1.52 m Loiano telescope are planned in 2001. We have already discovered among the stars in our sample a new field double-mode RR Lyrae : CU Comae [Clementini et al. (2000, AJ, 120, 2054)]. 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).

1.4.5 Development of specific software

Involved people at OAB: Clementini, Montegriffo.

We have fully developed and tested a number of software tools which allow: (i) to identify variable objects (VARFIND), (ii) to perform period searches and studies of single and multi-mode periodicities (GRATIS : GRAphycal Analyzer TIme Series) of the variables, 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 have been 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. We plan to make this software platform-independent and to upgrade its GRAphycal interface: FORTRAN routines will be converted to ANSI C, while the graphical interface presently developed in the SMONGO environment will be re-written using the TCL TK language.

1.5 Eclipsing binaries

Involved people at OAB: Bonifazi, Lolli.

The aim of the work is to increase the database of the fundamental stellar parameters and to test stellar structure and evolution. For this

purpose, photometric observations of many binary systems have been collected by means of various telescopes: 60 cm and 152 cm 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 152 cm 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 the year 2000 our activity has been devoted mainly to the implementation and testing of the latest release of a computer code (Wilson-Price code, see Barone et al. 1988) based on the physics of the Wilson-Devinney model, but using a fitting procedure different from the original differential correction one. This new approach to the solution of light curves is based on the "controlled random search" by Price (1976) and can resolve the ambiguities in the solutions.

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

1.6 Planetary Nebulae

Involved people at OAB: Stanghellini

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

In Cycle 8 we have observed about 30 LMC PNe with an innovative method involving slitless STIS/HST spectroscopy, capable of

revealing the morphology of LMC PNe (note that LMC PNe are spatially resolved only with space astronomy) 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:

(a) 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.

(b) 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: Shaw). The aim is to correlate PN shapes and central star evolution in a distance-bias free environment.

Our study has been extended to SMC PNe (55 HST orbits awarded in Cycle 9, PI: 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. The images are very interesting. We find that the morphological distribution of SMC PNe is different from that of the Galaxy or the LMC, indicating that morphology depends on galaxian metallicity.

In Cycle 10, two other Magellanic Cloud programs with STIS/HST have been approved, to complete the LMC survey (224 orbits, PI: Shaw) and to measure carbon abundances (28 prime orbits, PI: Stanghellini).

In the future, our LMC and SMC PN slitless spectra 'images' will form a database of extra-galactic PNe that will exceed by far in number the Galactic PNe observed with HST, providing an homogeneous sample for testing the evolutionary implications of metallicity variations in stellar evolution.

1.6.1 Morphology of Galactic Planetary Nebulae

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

(a) 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. We also concluded that the PN sample is really complete up to about 7 kpc.

(b) The distribution of PN nuclei on the logL-logT plane has been analyzed, and the results of Stanghellini et al. (1993) 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.

1.6.2 Post-Asymptotic Giant Branch Evolution

A long-lasting initiative has been undertaken [in collaboration with 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, 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 (i.e., the massive, slow wind at the end of the AGB, peeling the AGB star of most of its envelope, and forming the planetary nebula) 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.

Our post-AGB population synthesis code could be used in the future for a full host of different applications. In particular, we are currently applying it to the populations of elliptical galaxies, in order to explain the timing of the transition for post-AGB stars therein.

1.7 Pulsars

Involved people at OAB: D'Amico, Possenti.

1.7.1 Parkes Multibeam Pulsar Survey

In the last few 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 OAB. The survey uses the new 1.4 GHz multibeam receiver and a large filterbank system. The survey proved already to be very successful in the discovery of distant pulsars. So far, more than 600 new pulsars were discovered,

including about 15 young pulsars, two radio pulsars with very high magnetic field, and several new interesting binary systems. Among the most recent discoveries, there are two young energetc radio pulsars [Camilo et al. (2000), D'Amico et al. (2000), Manchester et al. (2000)].

1.7.2 Search of the Globular Cluster system for millisecond pulsars

Globular clusters are a rich source of millisecond pulsars. Exchange interactions in the core result in the formation of binary systems containing a neutron star which subsequently evolve, spinning up the neutron star through mass accretion. The millisecond pulsars formed in this way are among the most stable clocks in nature and are valuable for studies of the dynamics of clusters and the evolution of binaries embedded in them. However, they are quite difficult to find because the emission is weak and distorted by propagation through the interstellar medium, and the apparent pulse period may change rapidly because of binary motion.

About 50 % of the globular cluster pulsar population was discovered at Parkes by our group in the early 1990's. But since 1994, no further millisecond pulsars in globular clusters were found by any research team in the world. With the advent of the new Parkes 21-cm receiver, we decided to mount a new attack on the globular cluster system and attempt to break the long hiatus in such discoveries.

In order to improve our search capability, we are using a new filterbank system built at Jodrell Bank and Bologna. This filterbank features 512x0.5 MHz adjacent pass-band filters, making possible to remove the effects of dispersion in the interstellar medium more efficiently than previous searches. In fact, it allows the detection of millisecond pulsars with dispersion measures (DMs) of more than 200 $cm^{-3}pc$. The combination of this new equipment with the relatively high frequency of the multibeam receiver and its invaluable sensitivity gives an unique opportunity to probe distant clusters.

Also, because globular clusters are know to contain short-binary period millisecond pulsars, and because this class of objects is the very interesting one, we have implemented a new multi-dimensional code to search over a range of accelerations resulting from binary motion, in addition to the standard search over a range of DMs. This requires a huge amount of CPU resources (in Bologna we use a local cluster

of Alpha-500MHz CPUs and the Cray-T3E 256- processor system at CINECA), and the data management and storage is also a non-trivial issue (a typical integration on a single target produces 8Gbytes of data), but the results achieved so far largely justify the effort.

We have selected a sample of about 60 clusters, based on their central concentration and distance, and have discovered so far ten new millisecond pulsars in four clusters which were not known to contain pulsars before (D'Amico et al. 2000b, in press).

(a) The first interesting case is NGC6752. This cluster is believed to have a collapsed core and was already known to posses a large proportion of binary systems and several dim X-ray sources suggesting that millisecond pulsars are likely to be formed in its core. In this cluster we have first discovered a 3.26 ms pulsars in a 21h orbital period binary system, PSR J1910-59A. A peculiar characteristics of this pulsar is that, because of the relatively low DM, 34 $cm^{-3}pc$, it scintillates markedly, similar to the pulsars in 47 Tuc, so it is seen rarely. But, as we have already experienced on 47 Tuc, amplification due to scintillation might occasionally help in the detection of additional rather weak millisecond pulsar in the same cluster. In fact, devoting a large amount of observing time to this cluster, we have already found four additional millisecond pulsars previously unseen. Even more interestingly, all these four seem to be isolated. Such a large proportion of isolated/binaries (4/1) is not very common in globular clusters. It is possible that other hidden binaries (perhaps ultra-short binaries, or exotic submillisecond binary pulsars, or pulsar-black hole systems) might be present in this cluster. So, keeping observing and searching this cluster is certainly more than worthwhile.

(b) Another interesting case is the millisecond pulsar (so far the only one) discovered in NGC6397. This cluster is a prime candidate for globular cluster searches. It is close and has a very dense and probably collapsed core. It contains at least four X- ray sources which may be related to millisecond pulsars. Despite this, there was no known pulsar associated with NGC6397 prior to this search. In this cluster we have found PSR J1740-53, a relatively weak pulsar with a spin period of 3.65 ms and an orbital period of 1.35 days. This pulsar has been proved to be eclipsing for more that about 40 % of the orbital phase. Similar eclipses have been seen in other binary systems, but at variance with them J1740-53 is in a rather wide binary orbit of period 1.35 days, and has a relatively heavy companion, with a minimum mass of 0.18

$M_\odot$. It seems unlikely that a wind of sufficient density could be driven off a degenerate companion, and hence produce the observed eclipses. So, follow-up observations of this pulsar might represents a challenge in the understanding of the eclipse mechanism in millisecond pulsars.

(c) Three millisecond binary pulsars were found in another dense cluster, NGC6266. The first one, PSR J1701-30A, has a pulse period of 5.24 ms, an orbital period, 3.8 days, and the mass function gives a minimum companion mass of 0.19 M. This system is typical of many low-mass binary pulsars, both associated with globular clusters and in the Galactic field. But the two other systems, PSR J1701-30B and PSR J1701-30C belong to the class of short-binaries. They have respectively a pulse period of 3.6 and 3.8 ms and orbital periods of 3.8h and 5.2h. In particular, the detection of PSR J1701-30B was a challenge, because it shows acceleration peaks due to binary motion of up to 16 m/s^2 as well as significant acceleration derivatives.

(d) An ultra-short binary pulsar (so far the only one) was discovered in NGC6544. This cluster is also one of the closest, densest and most concentrated globular clusters known. Although no X-ray sources are known in the cluster, a radio continuum source of flux density was discovered at its center at the VLA, but up to now, pulsar searches have been unsuccessful. PSR J1807-24 has a spin period of 3.06 ms and is a relatively strong pulsars (see Figure 5) with a mean flux density of 1.3 mJy. Follow-up observations, made at Parkes and Jodrell Bank, showed that it is binary, with an orbital period extremely short, 1.7 hours, the second shortest known. Even more interestingly, the projected semi-major axis of the orbit is tiny, only 12 light-ms. The corresponding minimum companion mass is only 0.0089 $M_\odot$ or about 10 Jupiter masses.

We have proved that one of the key strategies in a search of the globular cluster system for millisecond pulsar, is to devote a large amount of observing to each target. Millisecond pulsars in globular clusters can be seen rarely: scintillation in low DM clusters, abnormally long eclipses, and unfavourable orbital phases in the case of ultra- short binaries might easily prevent the detection during a single observation. On the other hand, the hidden systems are more often the very interesting ones.

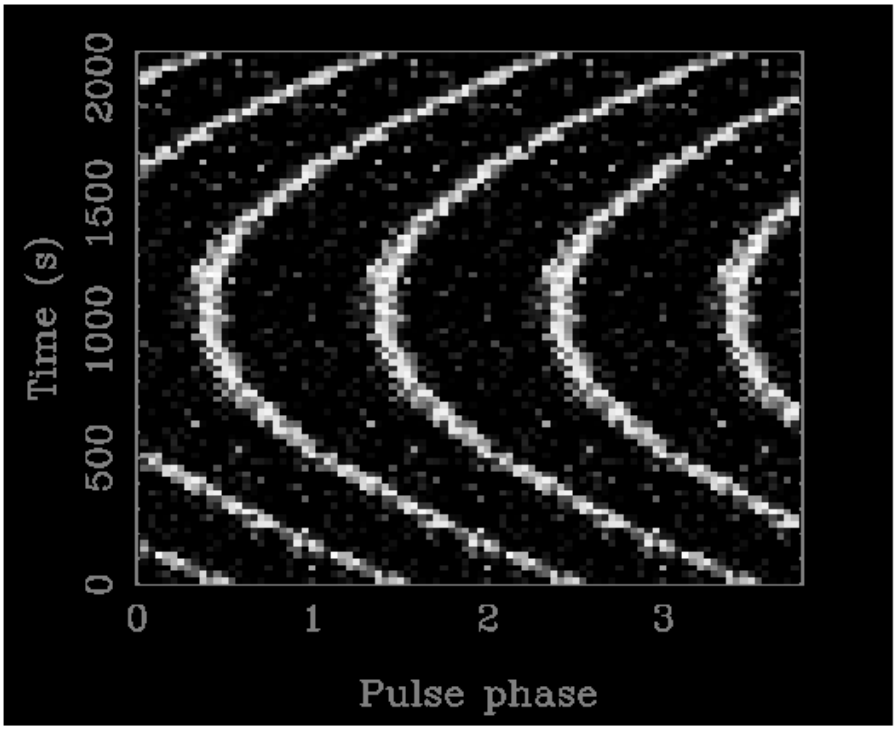


Figure 5: Variation of observed pulse phase over the 2100-sec discovery observation for PSR J1807-24 in the cluster NGC 6544. Each horizontal line in the figure represents the mean pulse profile resulting from 16 seconds of data folded with a period of 3.059415 ms. A pulsar with this apparent period would form a vertical trace in this diagram. The curvature shows that the apparent period varied significantly during the observation due to the pulsar's orbital motion. Although this pulsar is relatively strong (it was not detected in previous searches because of pulse smearing due to dispersion), weaker signals from such binary pulsars are difficult or impossible to detect with a conventional 'non-accelerated' search code.

1.7.3 Millisecond Pulsars Survey at the Northern Cross

The large scale survey for millisecond pulsars at 408 MHz is still in progress, using the Italian Northern Cross radiotelescope near Bologna. So far, about 35% of the sky at $\delta > 0^o$ was observed, resulting in the detection of 35 known pulsars, 5 known millisecond pulsars 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. 2000).

1.8 Integrated Light of Early Type Systems

Involved people at OAB: Greggio.

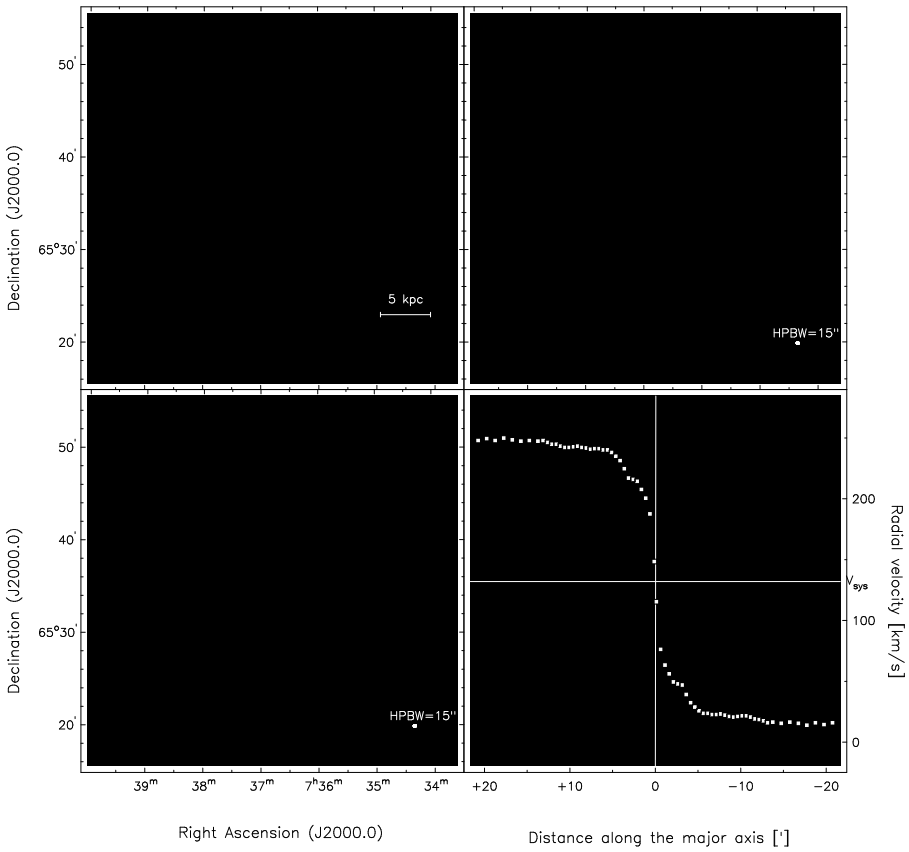
(a) Elliptical galaxies are a cornerstone in our understanding of the galaxy formation process in a cosmological frame. According to the currently most popular models, elliptical galaxies are the outcome of (multiple) merging of already formed units, as a natural result of the hierarchical models which 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 whether 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 Maraston (Univ. 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 2000 we analyzed the spectra of a sample of globular clus-

ters in the Galactic Bulge, obtained at the ESO 1.5 m telescope, to derive spectral indices. These data are essential to calibrate the models in the poorly constrained regime of high metallicity, and high $\alpha-$enhancement. Models for the integrated light from simple stellar populations will be computed, based on the most updated theoretical ingredients (stellar tracks and fitting functions) which account for the $\alpha-$enhancement. This will allow us to calibrate our models, for further applications to the spectra of Elliptical Galaxies. This work is done in collaboration with Renzini (ESO), Maraston, Saglia and Putzia (Univ. Munich).

(b) 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 Bender, Hopp and Thomas (Univ. 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



NGC 2403: Optical image (DSS), total HI map, velocity field and position-velocity diagram along the major axis. The dots show the rotation curve.

People involved 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. Nipoti, 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, to 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, and others find their main interest in radio studies of galaxies and quasars. Much of this research is based on an intensive use of the most advanced instruments available today (e.g. X-ray satellites like CHANDRA and XMM, the VLT).

2.1 Structure and evolution of galaxies

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

2.1.1 Theoretical studies and numerical simulations

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

Ciotti, in collaboration with Bertin (SNS-Pisa) developed a new analytical method to construct explicit, triaxial density-potential pairs, to be used in the description of structural and dynamical properties of elliptical galaxies. This method is also of considerable help in the numerical implementation of the Schwarzschild method of orbital superposition.

Ciotti, in collaboration with Bertin and Londrillo, constructed 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. Curiously, a particular case of the above mentioned density-potential pairs is the exact mass counterpart of this family of distribution functions.

Ciotti, in collaboration with Bertin and Del Principe (graduate student of SNS-Pisa) studied the effect of weak non-homology of elliptical galaxies along the Fundamental Plane.

On the subject of galaxy dynamics, Ciotti extended and generalized the study of the dynamical constraints on the distribution and amount of dark matter in the central regions of elliptical galaxies and bulges. This investigation is carried out by using analytical methods developed by Ciotti in the past years. The obtained results 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.

Ciotti, Londrillo and Nipoti (Univ. Bologna) are exploring the effect of radial orbit instability on galaxies belonging to the so-called Fundamental Plane, by using N-body numerical simulations.

Ciotti, in collaboration with Ostriker (Univ. Princeton) developed an evolutive scenario which links the X-ray evolution of elliptical galaxies to QSO evolution and activity. In this scenario we propose that the solution of the puzzling question of the lack of strong AGN activity in the large majority of elliptical galaxies containing a massive black hole at their center (activity naturally predicted in the standard cooling flow scenario) is due to an accretion mechanism modulated by radiation feedback. The feedback is due to Compton scattering of the radiation emitted by the accreting material on the electrons of the galactic hot gaseous halo. This scenario has been explored in great detail by using a specific numerical hydrocode which takes into account several aspects of radiative transfer.

Other research projects at various stages of development that are carried out by Ciotti, often in collaboration with students of the Department of Astronomy of Bologna University are: 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 and clusters of 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.

D'Ercole, together with Matteucci (OATs) and Recchi (Univ. Trieste), developed 2D numerical chemo-dynamical models of starburst galaxies mixing a pure hydrocode with programs usually adopted for standard one-zone chemical models. We can follow the abundance evolution of several elements (H, He, C, N, O, Mg, Si, Fe) and, contrary to previous models, we take into the account also the effect of SNIa explosions occurring at the end of the SNII stage. The model was tailored on the starburst galaxy IZw18 which has very low abundances and is very gas rich. Assuming a very low thermalization efficiency of SNIIs, most of the SNII ejects cool before being lost through the galactic wind. SNIa ejecta are lost easier because of the previous activity of SNII. As the ratio of α-elements/Fe is larger for SNII, it turns out that [α/Fe] is larger inside the galaxy than outside. Galactic abundances after 31 Myr are in good agreement with those of IZw18. Although this agreement is obtained assuming only one burst, the possibility that a previous burst occurred remains if the metallicity produced was lower than 0.01 $Z_{\odot}$. This latter possibility is currently studied (Recchi et al. 2001, in preparation).

2.1.2 Neutral hydrogen studies

People involved at OAB: Sancisi, Fraternali.

I. HI halos of spiral galaxies

Sancisi, Oosterloo and Fraternali (Univ. Bologna) have continued their study of the vertical distribution of neutral hydrogen and of the disk-halo connection in spiral galaxies. They have used HI observations obtained with the VLA and with the WSRT.

The VLA observations of the spiral galaxy NGC 2403 (see Figure) by Fraternali, Oosterloo, Sancisi and van Moorsel have shown the presence of gas (about 1/10 of the total HI mass) moving at peculiar velocities with respect to the regular rotation. This shows up clearly

in the position-velocity map along the major axis of this galaxy (see Figure) as faint, extended wings (the "beard") towards lower rotation velocities. A fraction of this 'anomalous' gas happens to be located in the two quadrants of apparent counter-rotation, quadrants that are 'forbidden' to the gas in an axisymmetrical potential. This 'forbidden' gas has a large projected velocity difference from the rotation curve and seems to be concentrated in the central region of the galaxy suggesting that it is related to star formation activity of NGC 2403. The anomalous gas is thought to form a thick disk or halo component surrounding a thin cold disk. It has a mean rotation velocity about 25-50 km/s lower than the thin disk and a radial inflow of about 10-20 km/s. The origin of this gas is still a puzzle. The HI study is being followed up with optical spectroscopy, X-ray observations and a numerical study of ballistic orbits in the gravitational potential of NGC 2403. So far, the most likely explanation appears to be that of a 'galactic fountain'.

Oosterloo and Sancisi have found another spiral galaxy, UGC 7766, observed in HI with the Westerbork Radio Telescope, to have anomalous HI emission with similar properties as NGC 2403.

II. Lopsided galaxies

Sancisi has continued the study of kinematically lopsided spiral galaxies. HI observations with the Westerbork Synthesis Radio Telescope (including WHISP) have been inspected to construct a sample of objects with lopsided kinematics. The properties of these galaxies are being analyzed.

III. The central regions of spiral galaxies

Swaters and Sancisi have undertaken a study of the rotation curves in the central parts of spiral galaxies. They have compared the shapes of the rotation curves obtained from optical and HI observations with the distribution of light as inferred from fotometric profiles.

2.2 Active galactic nuclei

2.2.1 Optical studies

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

I. Variability of Seyfert galaxies

In collaboration with Robinson and Axon, Stirpe is studying the statistics of broad emission line profiles in AGN, continuing to develop an automated procedure for the decomposition and analysis of the Hβ region. The information obtained from the Hβ profile will be combined with the corresponding data-set on Hα which has already been formed, in order to obtain information on the physical properties of the Broad Line Region (BLR) and to determine the origin of the great diversity of broad line profiles in the AGN population.

Within a collaboration led by Marconi (Arcetri Observatory), Stirpe has started a program to monitor the continuum and broad emission lines of a small sample of QSOs at $z \sim 2$ with the ESO VLT. This will greatly expand in luminosity the range of AGN for which we can estimate the size of the BLR, and provide clues on the evolution of these objects. Observation time has been awarded, starting in summer 2001.

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. These data have now been made available for the general astronomical community: the calibrated spectra can be inspected directly on the WEB[2], or downloaded (in FITS format). Under construction are animations that show the light curves of a spectral region around 5000 Å.

II. HST images of B2 radio galaxies

De Ruiter, in collaboration with Capetti (OA Torino), Parma and Fanti (IRA), and Morganti (NFRA, Netherlands), is studying HST images (in two colors, V and I) of about 65 radio galaxies selected from the B2 sample of low luminosity radio galaxies. Brightness pro-

[2] *http://boas5.bo.astro.it/~deruiter/seyf_spectable.html*

files were fitted to all galaxies, and these were used to obtain a detailed mapping of the (circum)-nuclear dust. As expected, in many of the galaxies the dust appears in the form of disks. Analysis of the data is in progress.

III. The environment of AGN

Zitelli, in collaboration with Focardi and Kelm (Univ. Bologna), is continuing the study of the relationship between nuclear activity and environment for active galactic nuclei. Ample evidences have been reported in the local universe of a complex environment around Active Galactic Nuclei and up to $z \sim 3$. However, while it is well established that radio loud quasar, 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 limit the statistical uncertainty we adopt a strategy based on the analysis of a statistically significant samples of nearby AGN and appropriate control samples selected on the basis of criteria independent of morphology and environmental properties. A sample of about 400 physical compact group is extracted applying an automatic code to 3 dimensional galaxy catalogue. The global properties of active galatic nuclei are analyzed, in particular Seyfert incidence within CG has been determined. From this analysis clearly emerges the dominance of Seyfert 2 that inhabit groups more often than Seyfert 1, confirming once more that locally dense environments discriminate against Seyfert 1.

2.2.2 Near-IR studies

People involved at OAB: Origlia, Pozzetti.

I. IR spectroscopic surveys

In collaboration with Oliva (TNG) and Maiolino (OAA) 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 broadening one can derive stellar and gaseous velocity dispersions and mass to light ratios, while from the absorption line equivalent widths an estimate of the stellar abundances and warm dust emission can be inferred. These quantities provide important constraints to age of the burst events and the starburst–AGN connection in the galaxy central regions.

II. The near-infrared spectrum of normal galaxies

In collaboration with Mannucci (CAISMI, Firenze) and others, 28 local galaxies haves been observed in the wavelength range between 1 and 2.4 μm in order to define template spectra of the normal galaxies along the Hubble sequence. All the spectra were obtained at the 1.5m IR-optimized telescope TIRGO; the long-slit spectrometer LonGSp was used. The resulting spread of the normalized spectra of each class is about 1% in K, 2% in H and 3% in J. Many absorption features can be accurately measured. Templates have been matched with those of Kinney et al. (1996) in order to build representative spectra between 0.1 and 2.4 μm. The resulting spectra are used to compute the k-corrections of the normal galaxies in the near-IR bands and to check the predictions of various spectral synthesis models: while the shape of the continuum is generally well predicted, large discrepancies are found in the absorption lines.

2.2.3 X-ray observations of AGN

People involved at OAB: Comastri, Vignali.

In collaboration with Vignali (Univ. Bologna) several observational programs aimed at understanding the high energy emission properties of different classes of AGN are carried out at the Observatory using data from ROSAT, ASCA and BeppoSAX X–ray satellites.

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 observations, the hard X–ray spectral properties of relatively bright AGN.

In this respect the most important results were the discovery, in a few objects, of spectral features due to highly ionized matter (iron lines and edges). A deep absorption edge at E > 8 keV is present in

the X–ray spectrum of the high luminosity nearby quasar PDS 456. The lack of any significant iron Kα emission suggests that the hard X–ray continuum is seen in transmission trough a highly ionized medium with a large column density ($N_H \simeq 4.5\times\ 10^{24}$ cm^{-2}). The presence of an extremely ionized, almost Compton thick absorber in a quasar makes this object a good candidate to test emission mechanisms and reprocessing in high luminosity objects. A deep K–edge at $\sim$ 7.8 keV has been discovered by BeppoSAX in the X–ray spectrum of the bright Seyfert 1 NGC 3516. The source also displays strong variability in the soft X–ray band due to variable (on a time scale of a few months) absorption by cold gas. The presence of line–like emission around 1 keV, which is clearly visible when the source is obscured, is likely to be due to the same gas responsible of the ionized iron edge. It is concluded that a highly ionized component is probably common in Seyfert 1 galaxies but can be detected only with good quality high energy spectra, and when the primary soft X–ray continuum is at least partially obscured. Finally, a deep ionized edge is present at $\sim$ 9 keV in the X–ray spectrum of the bright Narrow Line Seyfert 1 Galaxy Ark 564. The presence of an ionized iron line at $\sim$ 6.8 keV indicates that ionized reflection of the primary continuum is a viable explanation of the observed spectral features. There is no significative evidence of soft X–ray features (as claimed by several authors from the analysis of ASCA data) if the broad band (0.1–10 keV) spectrum is fitted with a thermal black–body like spectrum plus a steep power law component. The X–ray data for Ark 564, and also for a few other objects observed within the BeppoSAX Core program of Narrow Line Seyfert 1, were complemented by good quality quasi–simultaneous optical and UV spectra. These observations allowed to perform broad band spectral fits with accretion disk models. The results favor a low mass highly accreting black hole. The variability properties of hard X–ray emission in type 2 Seyfert galaxies have been investigated using BeppoSAX observations separated by approximately one year. The continuum flux shows variations up to a factor of two while the power law spectral index and the absorption column density remain constant. The results imply the presence of an homogeneous obscuring screen and constant physical conditions in the nuclear regions despite the continuum flux variations.

2.3 Surveys and Observational Cosmology

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

As an aid to observational cosmologists de Ruiter has made available (on the WEB) a collection of cosmological formulas. For a number of models (the standard Friedmann model, flat models with non-zero cosmological constant, and some more exotic ones) distances, volumes and look-back times are given as a function of redshift. In many cases the solutions are given in analytical form. The compendium can be found on the WEB[3].

2.3.1 VIRMOS deep survey

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

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

The visual spectrograph will be shipped to Chile in the first half of 2001 and after a few months of commissioning and testing will be operational at the beginning of 2002. 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 wide survey (16 sq.deg.) and about 50,000 galaxies from the deep survey (1 sq.deg.)] and the expected redshift coverage (up to z $\sim$ 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 tests of the predictions of various models of galaxy evolution (e.g. hierarchical versus monolithic models); b) precise estimates, on

[3] *http://boas5.bo.astro.it/~deruiter/cosmo/*

the basis of a single sample with well understood selection criteria, of the star formation history up to at least z $\sim$ 2; c) studies of the still uncertain nature of the extremely red galaxies (EROS), determining which fraction of them is actually associated to old elliptical galaxies at high redshift and which fraction is associated with dusty starburst galaxies.

As a by-product, since no morphological selection will be applied to the objects to be observed, this survey, with its expected $\sim$ 1000 AGNs down to I $\sim$ 24.0, will allow the study of the optical luminosity function and evolution of the faint (e.g. Seyfert-like) AGNs in a magnitude range where the selection of the AGN candidates with the standard color and morphological criteria is very difficult and, possibly, largely incomplete.

The survey, which will start in 2002, has already required a lot of scientific preparation. In the past years we have worked, together with the other teams involved in the project, in a number of activities needed to guarantee its success. In particular we have significantly contributed to the following issues:

- definition of the main scientific goals and of the observing strategy;
- participation to telescope time requests to ESO to obtain the needed photometric data in the U and K bands;
- definition of the data management and implementation of the survey database;
- development of software for the scientific data analysis.

Cappi is also examining how to discriminate between cosmological models from redshift surveys, in particular using the Alcock-Paczynski geometrical test and the statistics of gravitational lensing, with a focus on "quintessence" models (Cappi 2001, submitted).

2.3.2 K20 Redshift Survey

People involved at OAB: Mignoli, Pozzetti, Zamorani.

Bologna Observatory participates, with the observatories of Arcetri, ESO and Rome, to an ESO VLT Large Program (PI Cimatti (OAA)),

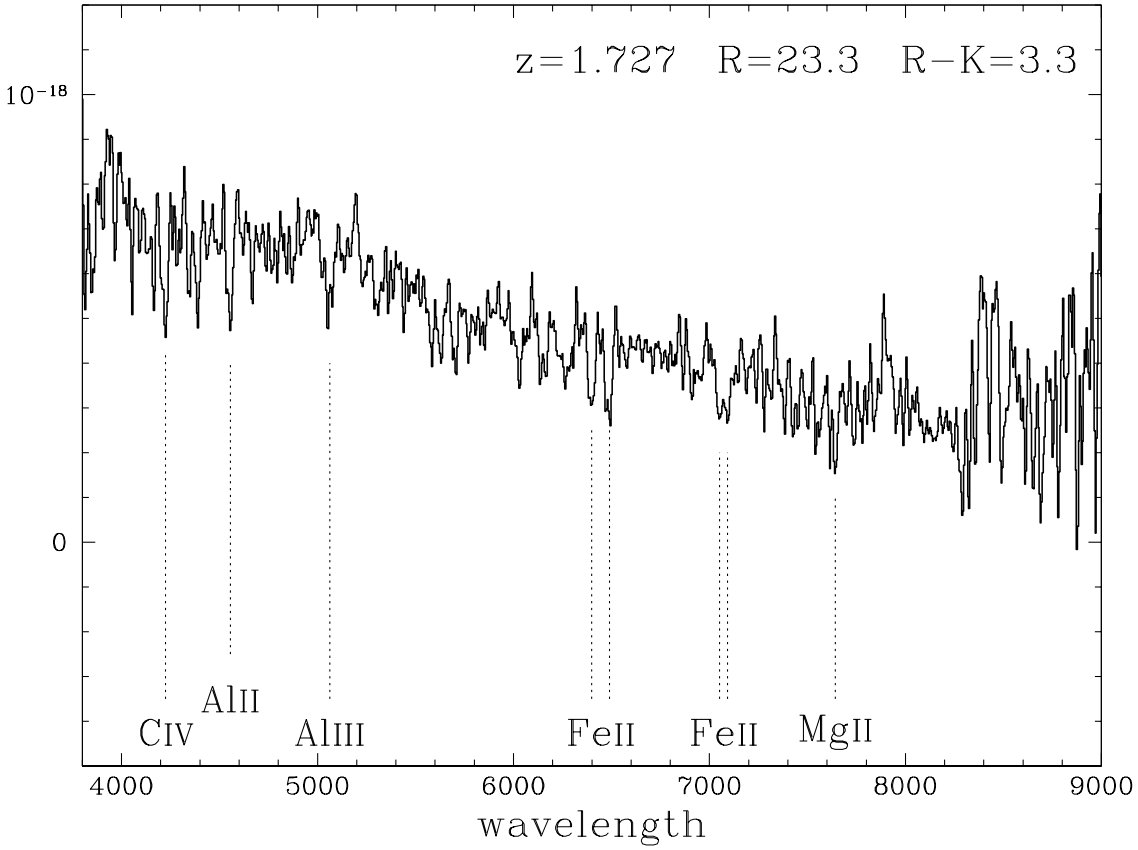


Figure 6: FORS2 spectrum of a z=1.7 galaxy in the K20 survey.

which started in 1999. This program (called K20[4]) aims at deriving the redshift distribution of a sample complete at $K < 20$, i.e. about 500 galaxies selected from a sub-area of the Chandra Deep Field (CDF) and from a field around the quasar 0055-2659 (z=3.7). Seventeen VLT nights have been allocated to this project over a period of two years. The survey makes use of both optical(FORS1/FORS2) and near-IR (ISAAC) 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 have been completed in 2000 and provided spectra of about 90% of the galaxies down to a completeness level of about $K < 20$. The last observations have been carried out using spectrograph FORS2 at the VLT-UT2, using for the first time the mask-cutting machine provided by the VIRMOS consortium. The use of the VIRMOS-like masks instead of usual slitlets, has allowed us to reach a greater multiplex gain: during the last run we have been able to observe up to 60 objects simultaneously with a single mask. Moreover, a relatively new observational technique for optical spectroscopy (called "slow beam switching") has been used, which has permitted to reach an exceptional quality in the removal of the sky background, of paramount importance in the case of spectroscopy of extremely weak objects (R=24-25). The data reduction and analyses are currently in progress, carried out in parallel at Bologna and Arcetri, with the goal to obtain a percentage as high as possible ($> 90\%$) in the determination of the redshifts of the survey objects. Moreover, in Bologna we have developed a software to reconstruct the K-band luminosity function from the spectro-photometric catalog down to redshift ~ 1 and have analyzed some galaxy pure luminosity evolution models to predict the redshift distribution to be compared with the observations, taking into account the influence and the uncertainties in different parameters (the cosmological parameters and the local luminosity function) as well as the surface brightness selection effects.

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

2.3.3 The ESO slice project

People involved 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 ~ 3500 galaxy spectra with $b_J \leq 19.4$ over an area of ~ 25 square degrees: the project (P.I. Vettolani, CNR Bologna) is the result of an international collaboration in which the Bologna Observatory is deeply involved.

This project produced a number of papers in the last years and during the year 2000 the analysis of the survey has been completed: the final results are mainly related to the clustering properties of ESP galaxies. The correlation function has been computed [Guzzo et al. (the ESP team), 2000, A&A 355, 1] both in redshift- and in real-space, finding:

- a general consistency with the results from other surveys;
- the presence of a "shoulder" with respect to a simple extrapolation of the canonical power-law shape for $r > 5$ h^{-1} Mpc;
- a luminosity segregation effect, with brighter galaxies ($M < -20.5$) a factor 2 more clustered than fainter objects.

These results have been confirmed also by the more general clustering analysis performed estimating the power spectrum of ESP galaxies (Carretti, Bertoni, Messina, Zucca, Guzzo, 2001, MNRAS in press).

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

2.3.4 Radio observations of the ESP Survey

People involved at OAB: De Ruiter.

The whole ~ 25 square degree region of the ESO Slice Project was observed at 20 cm with the Australia Telescope Compact Array, using the mosaicing technique (Prandoni, ..., de Ruiter, et al. 2000, paper I: A&AS, 146, 31; paper II: A&AS, 146,41; paper III: A&A, 365, 392; paper IV: 2001, A&A, in press). The resulting radio catalogue

[5] *http://boas5.bo.astro.it/∼cappi/esokp.html*

(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. New radio observations (10×12 hours) of the ESP region were done at 6 cm with the ATCA in the Fall 2000; the new data will provide spectral index information for a very large sample of faint radio sources.

2.3.5 Bright galaxies from WENSS

People involved at OAB: De Ruiter, Stirpe.

The Westerbork Northern Sky Survey has mapped the sky (above declination +30°) at 325 MHz (and is complementary to the NVSS survey at 20 cm made by the VLA). The overall catalogue contains about 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 preliminary list of about 4000 WENSS bright galaxies is now available.

2.3.6 X–ray Surveys

People involved at OAB: Ciliegi, Comastri, Mignoli, Vignali.

The BeppoSAX "High Energy Llarge Area Survey" (HELLAS) has surveyed several tens of square degrees of the sky in the 5–10 keV band down to a flux limit of about 5×10^{-14} erg cm^{-2} s^{-1}. The final sample consists of 147 sources. The source surface density of $\sim 17 \pm 6$ deg^{-2} at the survey limit corresponds to a resolved fraction of the hard X–ray background (XRB) of the order of 20–30 %. The extrapolation of the HELLAS logN–logS towards fainter fluxes with an Euclidean slope is consistent with the more sensitive (a factor 20) XMM–*Newton*

measurements in the same band. The number counts are also consistent with AGN synthesis model predictions. A sizeable fraction of the HELLAS sources are characterized by hard spectra, as can be judged from the hardness ratio analysis, suggesting the presence of intrinsic absorption. In order to extend the spectral coverage for the HELLAS sources a comprehensive study of their soft X–ray properties has been carried out using archival ROSAT and ASCA observations. Not surprisingly the average spectra of HELLAS sources are harder than those inferred from soft X–ray selected samples implying significant absorption. On the other hand the high detection rate (2/3) in the soft X–ray band suggests that soft (additional) components are common among hard X–ray selected objects.

The High Energy Large Area survey has been extended making use of *Chandra* and XMM–*Newton* data. The approach is complementary to deep pencil beam surveys (Giacconi et al. 2001, Hasinger et al. 2001) in that a different portion of the luminosity–redshift plane is covered. In order to 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 one would expect (i.e. narrow line AGN), especially at high redshift and/or luminosities where several hard X–ray sources are identified with broad line quasars. These properties can be explained by an extreme value of their dust to gas ratio or if the X–ray absorber is within the Broad Line Region. Another interesting result obtained thanks to the unprecedented positional accuracy of *Chandra* is the discovery of X–ray emitting optically faint galaxies. The relatively high X–ray to optical luminosity ratio suggests the presence of an active nucleus. The emerging picture indicates that 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.

2.3.7 The ELAIS Survey

People involved at OAB : Ciliegi, Mignoli, Pozzi, Zamorani.

ELAIS is a large European project, involving 19 different institutes, aimed at studying the nature and evolution of the extragalactic sources detected by the Infrared Space Observatory (ISO) in a selected area of the sky (covering 12 sq. deg.). Within this project, in collaboration with Gruppioni (OAPd), we have developed a new data reduction technique for ISOCAM LW data and have applied it to the ELAIS LW3 (15 μm) observations in the southern hemisphere (the fields called S1 and S2, covering respectively $2^\circ \times 2^\circ$ and $21' \times 21'$). The 15 μm data have been reduced and analyzed using the *LARI technique*, described in detail by Lari, Pozzi, Gruppioni et al. (2000). With this data reduction method, we have obtained two samples of 462 and 31 sources respectively in S1 and S2, with $S_{15\mu m} \geq 5\sigma$ and in the flux range 0.45 – 150 mJy. The fainter sources have been detected in S2 and in the central raster of S1 (S1_5), whose images have been obtained by combining respectively four and three single observations centered on the same position. The data reduction and analysis in S2 will be presented in the paper by Pozzi, Ciliegi, Gruppioni et al. (2001, in preparation), while the source catalogue in S1 and the relative parameter errors have been presented and discussed by Lari, Pozzi, Gruppioni et al. (2000).

From this data, we have obtained the 15 μm extragalactic source counts. The roughly 500 sources considered between about 0.45 and 150 mJy guarantee a high statistical significance of the integral and differential source counts in the previously uncovered flux range between the IRAS and the Deep ISOCAM Surveys. The bright part of the ELAIS counts is in agreement with the hypothesis of no evolution, while the fainter end shows a strong departure from no evolution models at about 2 mJy and an increase with super-Euclidean slope down to $\sim$0.4 mJy. This is in agreement with the results from ISOCAM Deep/Ultra-Deep Surveys, although our counts are slightly lower and our faint end slope is somewhat steeper than the counts drawn by these surveys. If all the 15 μm sources would be star-forming radio emitters, they would start dominating the sub-mJy 1.4 GHz counts at fluxes $S_{1.4\ GHz} <$ 100 - 150 μJy, as suggested also by optical identifications of radio sources. The results of this work will be presented in a paper (Gruppioni, Lari, Pozzi et al., 2001) in an advanced stage of preparation.

Moreover, in May 2000, we performed an optical spectroscopic survey of the radio and ISOCAM ELAIS sources in the norther hemisphere. As part of an International Time Programme and in collab-

oration with other member of the ELAIS Consortium, we obtained 8 nights with the multi-fibres instrument WYFFOS at the William Herschel Telescope. We obtained a total of 523 optical spectra (321 radio sources and 202 ISOCAM sources). The data reduction is still in progress. However a preliminary data analysis allowed us to identify the first hyperluminous infrared galaxy in the ELAIS area. This object has been detected by ISO at 6.7, 15 and 90 micron and is found to be (as confirmed by our optical spectroscopy) a broad-line , radio quiet quasar at redshift z=1.099. On the basis of a detailed model fit of the spectral energy distribution, we argue that the large IR luminosity ($L_{IR} \sim 1.2 \times 10^{13}$ $L_\odot$) arises in about equal parts from reprocessing of nuclear radiation by the dust torus and from a circumnuclear starburst. No evidence for lens magnification exist at this stage (Moriel et al. 2000).

2.3.8 Deep Extragalactic Surveys in the Marano Field

People involved at OAB: Mignoli, Zamorani.

The *Marano Field* is a southern sky area extensively surveyed in the optical (by means of multicolor imaging, slitless and slit spectroscopy, variability), in the X-rays (with a ROSAT $\sim$ 60 ksec integration) and in the radio band [with the ATCA radio telescope (S_{lim}=0.2 mJy) at 1.4 and 2.4 GHz]. Including the recently performed ISO observations and the incoming 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. The analysis of these data suggests that the efficiency of AGN selection based on the standard criteria (colors + morphology) decreases significantly at B > 23.0. At these magnitude most of the UV selected, point–like objects turn out to be extremely compact narrow emission line galaxies at z $\sim$ 0.6 - 1.2, with the classical broad line AGNs being only about 20% of the total number of candidates. These new data will allow to firmly estimate

the surface density of AGNs at B$\sim$23.5, where very few data exist, and to test at fainter magnitudes the existing models of luminosity function and evolution, which have now been firmly established on the basis of large samples (2dF survey) limited at B $\sim$ 21.

• In the course of the last year new photometric data have been obtained: using the WFI (Wide Field Imager) operating at the 2.2m ESO telescope, the Marano Field has been observed in five optical bands (UBVRI) in a more wide region, approximately 30x30 sq.arcmin. The field of view includes nearly the totality of the region covered by the XMM-*Newton* observations and therefore it will allow to identify a large fraction of X–ray sources until flux levels up to now largely unexplored, at least in the hard X–ray band. The data reduction is currently in progress.

2.3.9 The ROSAT Deep Survey in the Lockman Hole

People involved at OAB: Pozzetti, Zamorani.

The ROSAT Deep Surveys (RDS), in the direction of the Lockman Hole, is the most sensitive X-ray survey performed with the ROSAT satellite. About 70-80% of the X-ray background has been resolved into discrete sources and a nearly complete optical identification of the RDS has shown that the great majority of the source are AGNs. Bologna observatory is involved in this project in collaboration with Hasinger (Astrophysikalisches Institut Potsdam) and others.

An extension of the the ROSAT Deep Surveys (RDS) to fainter fluxes is the ROSAT Ultra Deep Surveys (UDS). The UDS reaches a flux levels of 1.2×10^{-15} erg cm^{-2} s^{-1}, a level 4.6 fainter than the RDS. A nearly complete spectroscopic sample of 94 X-ray sources based on low-resolution Keck spectra has been obtained: the majority are broad emission line AGNs (type I), 11% are groups and clusters of galaxies, while six X-ray sources remain spectroscopically unidentified. Optical/near-IR photometry with Keck indicates in 3 out of 6 the presence of an obscured AGN. Assuming that the spectral energy distribution in the optical/near-IR is due to stellar processes, their photometric redshift are in the range $1.2 < z_{ph} < 2.7$; these objects could belong to the long-sought population of type 2 QSOs, which are predicted by the AGN synthesis models of X-ray background (Lehmann, ..., Zamorani, ..., Pozzetti et al. 2001).

The eastern lobe of the unusual double-lobed extended X-ray source

RX J105343+5735 is confirmed to be a massive cluster at high redshift. Deep optical (Keck and CFH) and near-IR imaging (Keck+NIRC) have revealed a galaxy overdensity around the two peaks of the X-ray emission, with a significant excess of red galaxies ($R-K>5$) with colors typical of elliptical galaxies at $z>1$. We have applied our software for photometric redshift to the V,R,I,J,K data for the galaxies in this area. This revised version of the software uses a complete set of theoretical synthetic spectra (Bruzual & Charlot 1998), The mean photometric redshift derived for this sample is $\langle z_{ph}\rangle = 1.26$ and the dispersion is $\sigma(z_{ph}) = 0.13$. A Keck NIRSPEC spectrum of one of the bright central galaxies in this cluster shows a narrow Hα emission line at 1.485 microns, yielding a redshift of 1.263. The [O II] λ3727Å line from the gravitationally lensed arc is also detected, giving a redshift of 2.577 for the lensed galaxy and confirming prior measurements. The similarity of colors for the galaxies in the two X-ray lobes suggests that also the western lobe is at $z = 1.26$. This system may thus represent a pair of clusters in the process of merging (Thompson, Pozzetti, ..., Zamorani et al. 2001, in preparation).

2.3.10 Extremely red objects

People involved at OAB: Pozzetti, Zamorani.

A project aimed at studying the nature of the Extremely Red Objects (EROs) has been continued in collaboration with Cimatti (OAA) Daddi (Univ. Firenze) and Mannucci (CNR-CAISMI, Firenze). The EROs are defined in terms of their very red optical-to-near IR colors (as R-K>5 or I-K>4). Originally this selection was aimed at selecting old (> 1 Gyr) passively evolving elliptical galaxies at intermediate redshift (1<z<2), but it was soon discovered that young star-forming dusty galaxies can show similar colors and therefore be selected in the same surveys. It is crucial to better understand the relative contribution of these two populations to the EROs, because this can put important constraints on the models of galaxy formation.

We have studied additional ways for discriminating between the two possible populations both in the framework of the stellar population synthesis models and by using observed spectra (Pozzetti & Mannucci 2000). We have found that old ellipticals and dusty starbursts are expected to show different colors in the (I-K) vs. (J-K) diagram for the redshift range 1<z<2, providing thus a useful tool

to classify EROs in large samples up to K<20. This is mainly due to the fact that old galaxies at these redshifts have a strong 4000Å break at $\lambda < 1.2\mu$m (J band), while dusty galaxies show a smoother spectral energy distributions and therefore redder J-K colors. The selection criterion has been also compared with the properties of EROs of known nature. In addition, we have shown that this color selection criterion is also useful to separate the EROs from brown dwarf stars showing similar optical-to-IR colors.

We have moreover presented the results of a wide–field survey (701 arcmin^2) for EROs, the widest so far, based on Ks and R band imaging (Daddi et al. 2000). The survey is 85% complete to $Ks \leq 18.8$ over the whole area and to $Ks \leq 19.2$ over 447.5 arcmin^2. A complete sample of about 400 EROs with $R-Ks >5$ was selected. The distribution of the EROs on the sky is strongly inhomogeneous, being characterized by over densities and large voids. We detected at the 8σ level a strong clustering signal of the EROs which is about an order of magnitude larger than the clustering of the K-selected field galaxies in the same magnitude range. A smooth trend of increasing clustering amplitude with the $R-Ks$ color is observed. These results are strong evidence that the largest fraction of EROs is composed of high–z ellipticals, of which we detect for the first time the $z > 1$ large scale structure clustering signal. We show how the surface density variations of the ERO population found in our survey can explain the highly discrepant results obtained so far on the density of $z > 1$ ellipticals.

2.3.11 Extragalactic Background Light

People involved at OAB: Ciliegi, Comastri, Pozzetti.

I. The Optical/IR Extragalactic Background Light

In collaboration with Madau (IoA, Cambridge), Pozzetti has investigated the constraints imposed by the observed extragalactic background light (EBL) on the cosmic history of star formation and the stellar mass density today. The cumulative emission from young and evolved galactic systems, as well as from AGNs, is recorded in this radiation. 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 (Madau & Pozzetti 2000,

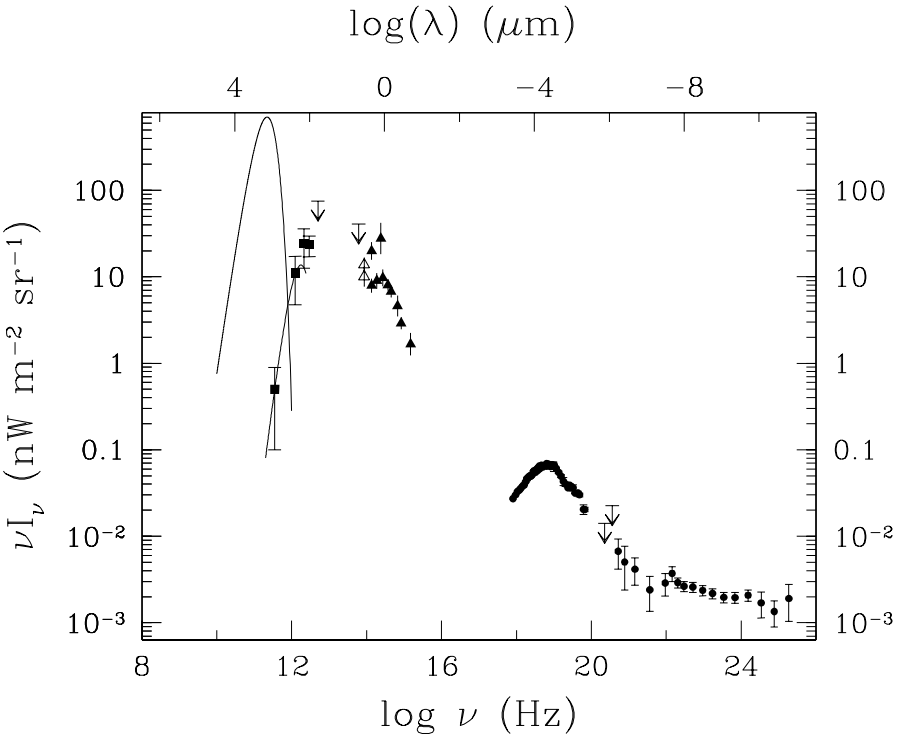


Figure 7: The overall cosmic energy density spectrum (νI_ν vs. ν): a compilation of most recent datasets, from microwave to high energy gamma rays.

Pozzetti & Madau 2000). A lower limit of $\Omega_{g+s}h^2 > 0.0015\,I_{60}$ can be set to the visible (processed gas + stars) mass density required to generate a total (Optical+FIR) EBL at a level of $60\,I_{60}\,nW\,m^{-2}\,sr^{-1}$; our "best-guess" value is $\Omega_{g+s}h^2 \approx 0.0023\,I_{60}$, which implies a mean metallicity at the present–epoch of $y_Z\Omega_{g+s}/\Omega_b \approx 0.2\,Z_\odot$. Assuming a standard black hole accretion model for quasar activity and using recent observations of the quasar population and new synthesis models for the cosmic X–ray background, we estimate a present mass density of QSO remnants of $\rho_{\rm BH} \approx 3 \times 10^5\,M_\odot\,Mpc^{-3}$ for a 10% efficiency of accreted mass–to–radiation conversion. The quasar contribution to the brightness of the night sky is $I_{\rm QSO} \approx 2\,nW\,m^{-2}\,sr^{-1}$ (Madau, Haardt & Pozzetti 2000).

II. X–ray and FIR background

Comastri investigated AGN synthesis models for the X–ray background, making use of the most recent data obtained by the first deep XMM–*Newton* and *Chandra* surveys complemented by shallower, larger area BeppoSAX and ASCA surveys. Even though there is a relatively good agreement between model predictions and the present observational constraints 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 order to reproduce the high energy counts measured by BeppoSAX and XMM–*Newton*, a large fraction of highly absorbed ($\log N_H$ = 23–24 cm^{-2}), luminous ($L_X > 10^{44}$ erg s^{-1}) AGN is needed. A sizeable number of more heavily obscured, Compton thick objects cannot be ruled out but it is not required to fit the counts. The agreement between the model predicted absorption and luminosity distributions and the optical identification breakdown can be obtained only assuming that the X–ray classification is decoupled from the optical one. The large variety in the optical classification of faint X–ray obscured sources lend support to this scenario. 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. The synthesis model for the XRB has been adopted to estimate the AGN contribution to the far infrared background. A detailed analysis of the multiwavelength properties of X–ray selected sources allowed to estimate their broad band spectral energy distribution as a function of the absorbing column density. The results indicate that the sources of the hard XRB do not provide a significant contribution at longer wavelengths with the exception of heavily obscured Compton thick objects which might constitute a sizeable fraction of the far–infrared sub–mm background.

III. FIRBACK

Ciliegi is involved in the FIRBACK (Far Infrared BACKground) survey, which is one of the deepest surveys carried out at 170 micron with ISOPHOT onboard ISO, and is aimed at the study of the structure of the Cosmic Far Infrared Background. During the year 2000, a work with the analysis of resolved sources has been presented. 196 galaxies with flux S$>$ 3σ (σ = 45 mJy) are detected in the area of

3.89 square degrees. Counts of sources with flux S> 4σ present a steep slope of 3.3 $\pm$ 0.6 on a differential logN-logS plot between 180 and 500 mJy. This strong evolution compared with a slope of 2.5 from Euclidean geometry is in line with model implying a strong evolving Luminous Infrared Galaxy population. The resolved sources account for less than 10 per cent of the Cosmic Infrared Background at 170 micron, which is expected to be resolved into sources in the 1 to 10 mJy range (Dole et al. 2000).

2.4 Galaxy clusters and large-scale structure

2.4.1 The Shapley Concentration

People involved at OAB: Bardelli, Zamorani, Zucca.

A long term project in which the extragalactic group is involved is the multiwavelength study of the Shapley Concentration, the richest supercluster in the nearby Universe. This study is devoted to investigate the effect of the environment and of the merging phenomena on the physics of clusters and on their galaxy population. In particular, the central part of supercluster are ideal laboratories where to study dynamical processes, given the higher peculiar velocities induced by the density excess.

The main results of this work in the year 2000 are:

- 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).

- In order to explore the effect of cluster merging on the spectral properties of the galaxy population, a Principal Component Analysis technique was applied to a sample of about 2000 spectra (Baldi, Bardelli & Zucca 2001, MNRAS in press). Analyzing the spectral type distribution as a function of the local density, previously determined (Bardelli, Zucca & Baldi 2001, MNRAS 320, 387), it has been concluded that the merging phenomenon was not able to substantially modify the morphology-density relation. Moreover these results are consistent with the literature

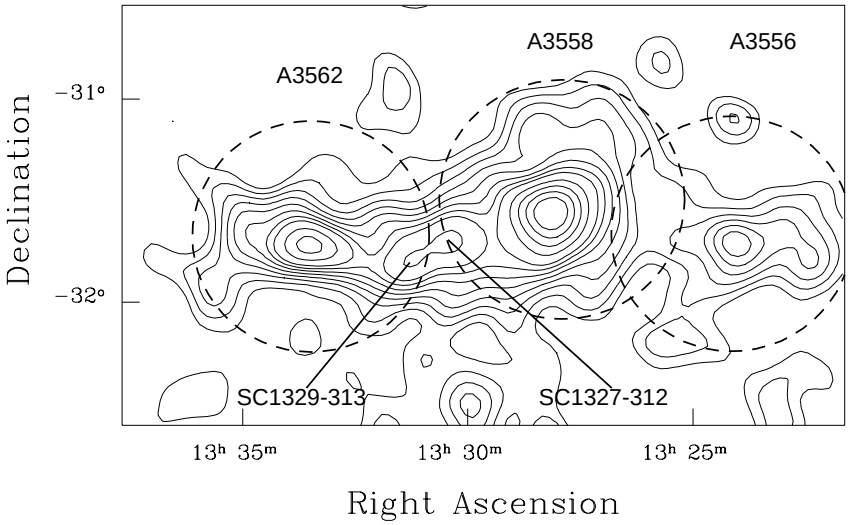


Figure 8: Complex of merging clusters in the core of the Shapley concentration.

claims that the star formation rate in cluster is lowered with respect to the field.

- A wide radio survey was performed on the two structures formed by interacting clusters (the A3558 complex and the A3528 complex), which dominate the core of the Shapley Concentration, finding that in the A3558 cluster complex the merging "switched off" the radio sources, producing a lack of radio galaxies (Venturi, Bardelli et al. 2000, MNRAS 314, 594). On the contrary, the luminosity function of radio galaxies in the A3528 cluster complex is consistent with that of normal clusters (Venturi, Bardelli et al. 2001, MNRAS in press). The conclusion is that the different behavior in the two complexes is due to the age of the merging: the A3558 complex is in an advanced merging stage, while the A3528 complex is a young merging event.

- In order to investigate the link between radio and X-ray properties in merging clusters, ROSAT and Beppo-SAX maps of clusters in the Shapley Concentration were analyzed (Ettori, Bardelli, ..., Zamorani, Zucca 2000, MNRAS 318, 239) and the physical parameters (temperature, gas distribution and metallic-

ity) of the intercluster medium were derived. Using two Beppo-SAX pointed observations, we studied the region in the A3558 complex where a shock is expected, finding no evidence of regions with enhanced temperature, indicating that the gas is in the expansion phase and thus reinforcing the hypothesis that the A3558 complex is an old merging (Bardelli et al. 2001, MNRAS submitted).

Further information about this project can be found on the WEB[6].

2.4.2 The distribution of galaxies as a function of luminosity

People involved at OAB: Cappi.

Cappi, in collaboration with Benoist, da Costa (ESO), and Maurogordato (Obs. Côte d'Azure), has analyzed the statistical properties of the galaxy distribution with the SSRS2 catalogue (da Costa et al. 1994). He has also analysed the galaxy clustering in the ESO Slice Project (Guzzo et al. 2000). These works have clearly shown the biasing in the distribution of galaxies as a function of their luminosity. Presently Cappi is studying the environment of the most luminous galaxies, which show a correlation length comparable to clusters, but seem to reside in "Local Group-like" systems (Cappi et al. 2001, in preparation).

2.4.3 Optically selected galaxy clusters with z≤ 1

People involved at OAB: Bardelli, Zucca.

From the wide angle multicolor ESO Imaging Survey (EIS), a sample of few hundreds of galaxy cluster candidates have been extracted, using both matched filter algorithms and color slicing techniques. The estimated redshift range of these candidates has a tail reaching $z \sim 1.3$. This sample will allow to determine the structural parameters and the galaxy population characteristics of cluster of different richness in a wide range of redshifts (Da Costa et al. 2001, proc. of ESO workshop on Deep Field, in press).

A great effort has been undertaken in order to have a spectroscopic confirmation of a subsample of these EIS clusters.

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

Candidates in the range $0.2 < z < 0.6$ have been observed with the EFOSC2 spectrograph at the ESO 3.6m telescope (Ramella et al. 2000, A&A 360, 861; Biviano et al., in preparation), testing at the same time various strategies for selecting cluster members, as the use of photometric redshifts and color–magnitude relations for early-type galaxies.

For clusters in the redshift range $0.7 < z < 0.9$, the observations have been performed with the use of the FORS1 and FORS2 spectrographs at the VLT, obtaining more than 500 spectra: data are in the reduction phase.

For the farthest objects ($z \sim 1$), time on the VIMOS Integral Field Unity at the VLT has been allocated for 2001.

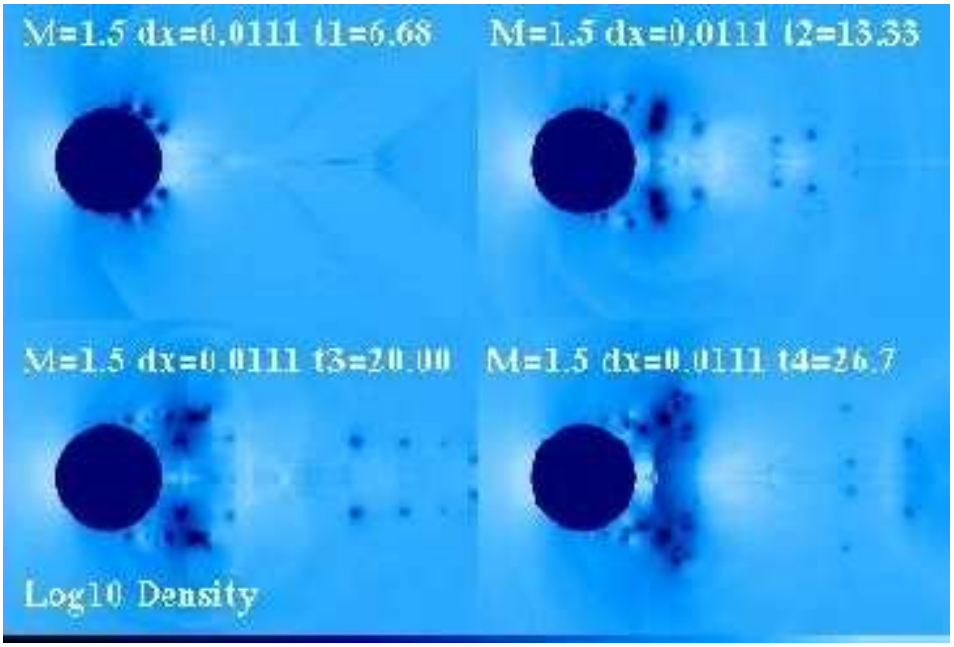
2.4.4 Galaxy clusters and large-scale structure

People involved at OAB: Bardelli, Cappi, Zucca.

Cappi is involved in a project with researchers at the Observatoire de la Côte d'Azur (Maurogordato, Benoist, Ferrari, Slezak) and at the CEA/CEN in Saclay (Arnaud, 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 based on optical observations at the ESO 3.6m and CFHT telescopes, and on X-ray observations with ASCA and ROSAT, and with Chandra and XMM. A number of results have been obtained with 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). New spectroscopic observations have recently increased the number of known redshifts, giving a detailed map of the substructures and dynamics of this complex system, while more imaging and spectroscopic observations are scheduled in 2001, in order to study the star-forming galaxies in the cluster and their distribution. A dynamical study is currently carried out also on another, regular cluster (A1413).

Bardelli, Cappi and Zucca, in collaboration with researchers in in Milan and Padua (De Grandi, Moscardini, et al.) are analyzing BeppoSaX observations of two cluster pairs in the Corona Borealis Supercluster; together with the available redshifts, it will be possible to analyze the consequences of the merging event on the energetics, internal structure and dynamics of clusters and the interplay between the ambient density, the dark mass, the gas and the galaxy population.

3 Numerical studies and software development



Shock diffraction on a sphere.

Involved people at OAB:

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

3.1 Turbulence and numerical schemes

Involved people at OAB: Bedogni, Londrillo.

Bedogni, in collaboration with Di Fazio (OAR) and Urpim (Univ. St. Petersburg), 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 description 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).

A 3D model for the study of propagation of circular polarized and arc-polarized Alfven waves in hot and cold plasmas has been analyzed by Londrillo using numerical simulation. This study has been performed in collaboration with Velli and Del Zanna (OAA) and with Grappin (Obs. de Meudon, Paris). Reports on this research activity have been presented at the Meudon workshop on Astrophysical Plasmas (Meudon-15-26 May) and at the 'Conferenza Nazionale Fisica del Plasma' (Cetraro, September 20-23). Specific results on the parallelization of the MHD code developed by Londrillo and Del Zanna have also been achieved and presented at the Cineca Workshop on Numerical astrophysics (Bologna, june 22).

Londrillo (in collaboration with Ciotti, see also Section 2.1), started a numerical study of the equilibrium solution of the collisionless Vlasov equation describing truncated toroidal density distributions. In particular, a numerical technique based on polynomial expansion and Newton iteration has been implemented to solve efficiently the associated non–linear Poisson equation for the potential–density pair.

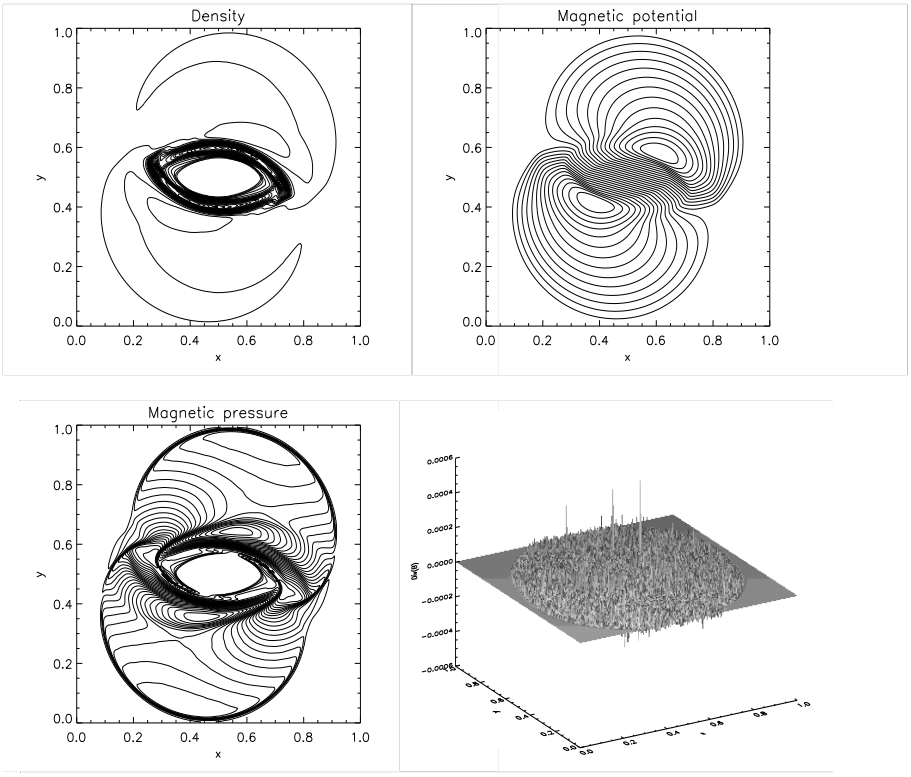


Figure 9: The 'fast rotor' test for our high-order shock-capturing MHD code (Londrillo and Del Zanna, 2000), where a high-density disk spins rapidly in an initially uniform magnetized plasma.

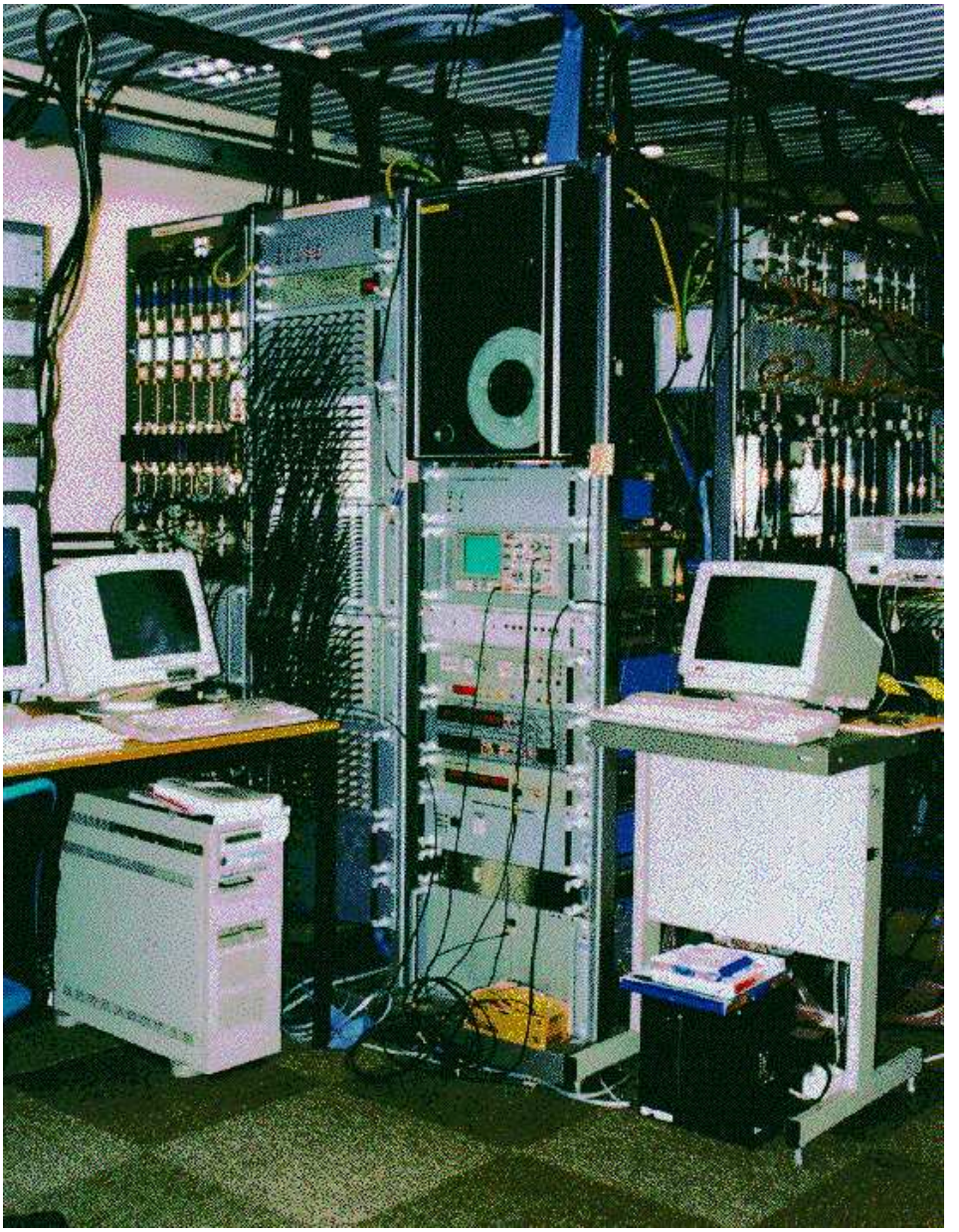
Londrillo (in collaboration with Ciotti and Nipoti (Univ. Bologna), see also Section 2.1) is involved in a detailed study of stability of anisotropic models of Elliptical galaxies. He implemented and checked the numerical tools necessary for the investigation of this problem (a "tree-code" and a "Particle-Mesh" scheme) have been

3.2 StarFinder

Involved people at OAB: Diolaiti, Parmeggiani.

StarFinder is a code for high precision photometry and astrometry of crowded fields, designed for well-sampled Adaptive Optics (AO) images with high and low Strehl ratio. The recognition of the stars and the determination of the photometry and astrometry are accomplished matching the presumed stellar images with a numerical PSF estimate, extracted directly from the image. This strategy allows to account for the complicated shape of the PSF, resulting from the residual atmospheric turbulence and various instrumental effects. The code has been successfully applied to high Strehl AO images (e.g. Galactic Center observations taken by Rigaut et al. 1998) and to HST undersampled data whose spatial resolution has been enhanced by dithering techniques (the starburst galaxy NGC1569 and multi-wavelength observations of NGC1705). Tests on HST undersampled images of M80 and NGC288 indicate that the StarFinder performance on this kind of data is only marginally worse than that of other methods. StarFinder is written in IDL language and is provided with a graphical user interface, so that no knowledge of IDL is required. It has been tested on Windows and Unix platforms supporting IDL v.5.0 or later. The computation time is proportional to the number of stars; the analysis of a 368x368 images with about 1000 objects requires a few minutes on a normal PC (Pentium Pro - 128Mb RAM - 650MHz). The package and its technical documentation are directly available through World Wide Web at the home page of the Bologna Observatory. The most important future developments include the PSF spatial variation, both in AO and seeing-limited observations, and a technique to handle undersampled HST data.

4 Instruments and Techniques



The pulsar data acquisition system of the Northern Cross Radiotelescope

Involved people at OAB:

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

4.1 Light Pollution

Involved people at OAB: Zitelli.

Since 1999 Zitelli is involved in the astronomical site protection. After having settled a Technical Standard UNI10919 for the reduction of light pollution, to limit the upward scattered luminous flux emitted by the lighting devices and defining the technical requirements of lighting installations to that purpose, she has contacts with public administrations having to apply this standard.

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 ambient.

4.3 TNG

Involved people at OAB: Zitelli.

Zitelli (with Ortolani from Padova, Mancini from Napoli, and Porceddu from Cagliari) is a component of a working group "site testing" for the Telescopio Nazionale Galileo (TNG). At present, close to the Galileo site, there are the two towers for the meteo and seeing monitoring. Analysis of the first data coming from the meteo tower are in progress and the first results have been presented at the IAU Technical workshop "Site 2000". Further experiments are in progress to have a more complete characterization of the TNG site.

Zitelli and Ciattaglia (with Held from OAPd) are conducting the final test on slit drilling machine for low dispersion spectrograph at the Galileo National Telescope. The machine is now available to the astronomers to obtain multi objects spectroscopy. 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 6x9.5 arcmin^2.

4.4 The VLT Project VIRMOS

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

The OAB 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 spectroscopy from 0.37 to 1.8 microns, with unsurpassed efficiency for large surveys.

The OAB is mainly involved in the development of the imaging and astrometric part of the DRS (Data Reduction Software) and of

the RTD (Real Time Display). DRS software must perform on-line (pipeline sequence) and off-line data analysis from raw data to fully reduced images (both direct imaging and spectra) while the RTD must allow quick-look of the data and a minimal on-line data assessment (see 8.8).

4.5 The Pulsar Project

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

I. New pulsar data acquisition for the Medicina 32m dish

Involved people at OAB: D'Amico, Innocenti.

So far, pulsar observations at Bologna were performed using the E-W arm of the Northern Cross radiotelescope. This is a transit instrument, and while it is very useful for surveys, it has strong limitations for further studies. So, for instance, in the case of the millisecond pulsar discovered at the Cross, PSR J0030+0451 (D'Amico, 2000, 177th IAU Colloquium) we needed to apply at Parkes in order to follow-up this object. Indeed, at Parkes we made interesting observations, which were the subject of a undergraduate student project (Nicastro, Nigro, D'Amico, Laumiella & Johnston, 2000, A&A in Press). This convinced us of the utility to upgrade the 32m dish by installing a pulsar data acquisition system.

II. BPMS: Bologna Pulsar Multiprocessor System

Involved people at OAB: D'Amico, Possenti, Di Luca, Lolli.

The new-generation pulsar search experiments in progress at Parkes produce a huge amount of data. This is due to the relatively high time resolution (125 or 250 μs) and frequency resolution adopted (up to 512 channels for the centre-beam, and up to 13x96=1248 channels for the multibeam). For instance, a typical integration on a single Globular Cluster of 2.3 h, sampling the 512 channels of the centre-beam at 125 μs, produces an array of 512 x 64Msamples = 32 Gsamples (4 GB, packing the data at 1-bit/sample). In the multibeam survey of the Galactic plane, a typical integration of 35 min, sampling the 96 channels of the 13 beams at 250 μs, produces a multidimensional dataset

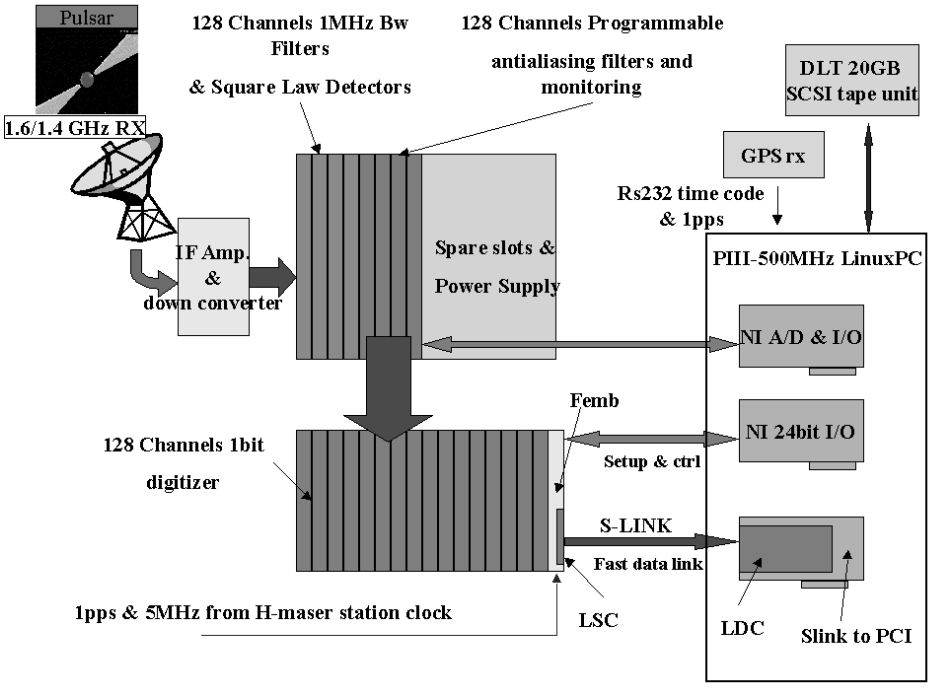


Figure 10: The new pulsar data acquisition system for the 32m dish. The system is controlled by a PC based Lynux machine and is designed to operate at 20cm. It consists of a dual polarization 2x64 channels filterbank (1MHz each), a 128 channels 1-bit digitizer, and a UT-phased sampling generator. All the various hardware components have been already built and tested, and we are now in the process of writing the online software, and should be able to initiate the observations around May 2001.

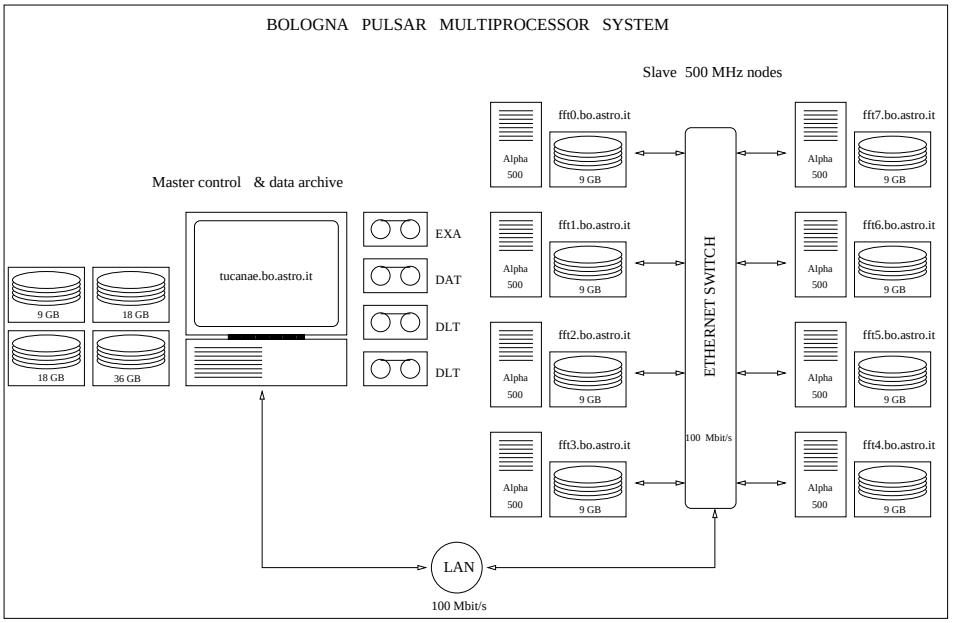


Figure 11: Multiprocessor system dedicated to the analysis of the pulsar data in Bologna. In this system, full parallel performances are achieved by segmenting the pulsar parameter space into a number of sub-volumes equal to the number of slave-processors available. In this way, performances of up to several GFLOPS are achieved.

containing 96 x 13 x 8Msamples = 10Gsamples (1.3 GB, packing the data at 1-bit/sample). The total number of pointings required to complete the survey ($\sim$ 2600) correspond to $\sim$ 3 TBytes. It is clear that supecomputing facilities and excellent pipelines are required to process these data. On the other hand, we proved these experiments to be very succesful, with more than 600 new pulsars discovered during the multibeam survey of the Galactic plane, and a (still growing) large number of binary millisecond pulsars discovered in globular clusters. In order to mount an efficient attack to the data processing, at Bologna we have designed and implemented a powerful multiprocessor system (Fig.8).

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 Greggio, as responsible of the project documentation.

In year 2000 the OmegaCAM project has had a major development, through the milestones of the Kick-Off meeting (April 7 and 8/2000 - Groeningen, NL), the Conceptual Design Review (July 7, 2000-Garching, ESO) and the Preliminary Design Review (December 19, 2000-Garching, ESO). A large amount of documentation has been released fot the Design Review, including plans, technical reports and drawings. A few OmegaCAM team meetings have taken place in Munich and Goettingen. Most of the comunication among the Consortium members and the official communication towards ESO, has been managed by Greggio, through the OmegaCAM WEB page at the USM-Munchen.

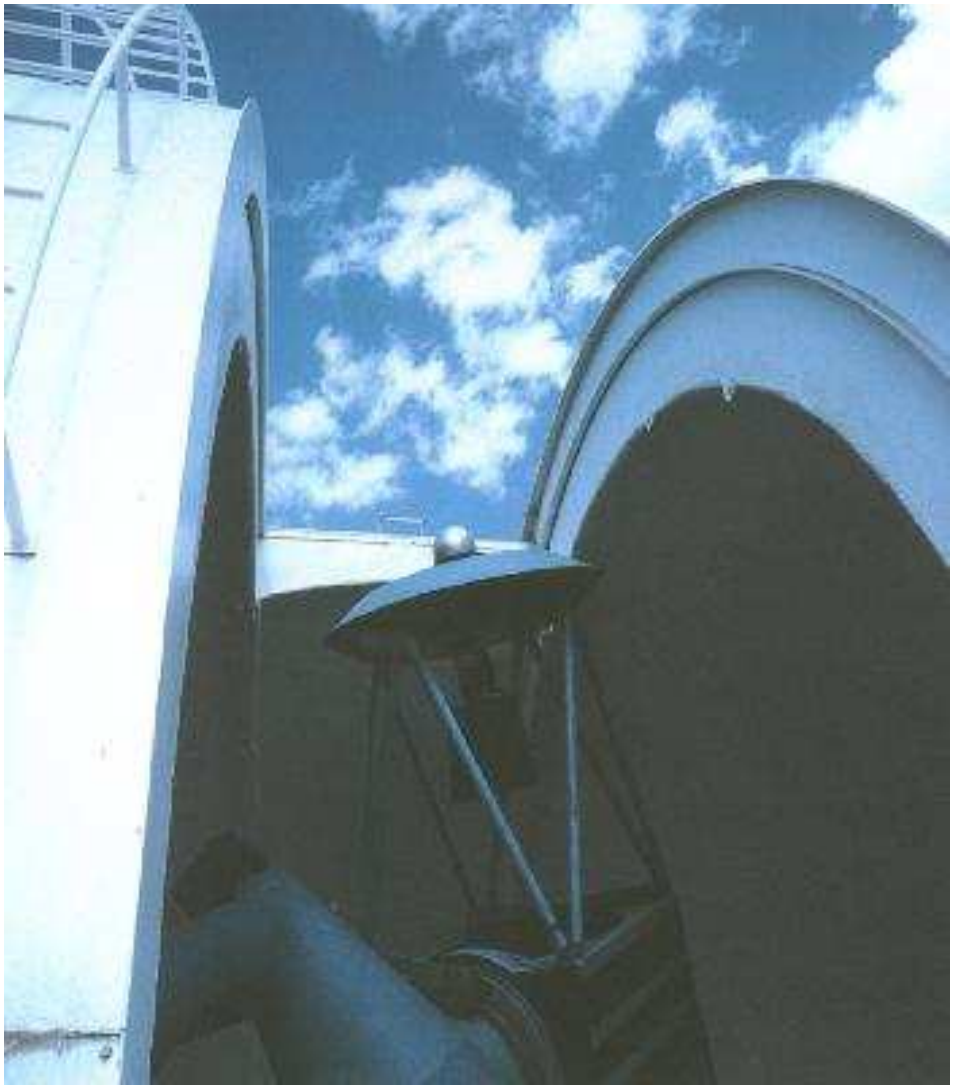
4.7 FLAMES project

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

The Bologna Observatory is member of an international consortium working on the construction of FLAMES. FLAMES is an instrument facility for multi-object spectroscopy under development at the ESO. It consist of several components: a Nasmyth corrector, a fiber positioner, a fiber link to the UVES spectrograph, an high and intermediate resolution optical spectrograph (GIRAFFE) with its own fibre system, a coordinating observing software, Flames OS, a future intermediate resolution IR spectrograph. As part of the Ital-FLAMES

consortium, the OAB provides the Templates for FLAMES in all observing modes. This activity is carried out by the contractor Dr. Rossetti under the supervision of Ferraro and Merighi, in collaboration with personnel at ESO and the OA Trieste, and with the coordination of the Ital-FLAMES consortium P.I Cacciari.

5 Loiano observing site



The 152 cm telescope at the Loiano observing site

Involved people at OAB:

- *Scientific staff:* R. Merighi, V. Zitelli.
- *Technical staff:* S. Bernabei, A. De Blasi, R. Gualandi, L. Fabbroni, 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 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 Zitelli.

The **152 cm telescope**, dedicated to G.D. Cassini, was built by Reosc and has been operating 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, Spectrograph and camera), based on transmitting optics ranging from 330 to 1100 nm. It is possible to choose, as collecting device, between two CCDs: (a) a new CCD camera EEV 1340x1300 or (b) a Thomson CCD 1024x1024 (as backup system).

   There are two set of filters available: a standard Johnson- Kron-Couisins system and a Gunn system.

2. A "classical", cooled, five colors Photoelectric Photometer

3. A two channels photoelectric Photometer (3 colours).

BFOSC has been the most scheduled instrument, with about 80% of the total allocated time, since its flexibility takes into account the meteo condition of the 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 to a f/20 Cassegrain and is now 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 Operations 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 for about 350 nights/year, but only about half of this time is really useful for observations, due to weather conditions. The statistics of the last years is given in Table 2. Time is allocated every 6 months, 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 section 8.6 for an updated situation of the Loiano computer facility. It is possible to have a pre reduction of the observations with a PC in a local network with the PC for the observations. MIDAS and IRAF packages are also available.

5.2 Applications to 152 cm Telescope

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

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

Table 2. Cassini Telescope – Nights used per year

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

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

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

5. Natta, A. and Gomez M.: *Young stellar cluster: large amplitude variable stars*

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

7. Silvotti, R.: *WD and pre-WD seismology*

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

9. Tozzi G.P.: *Polarimetry of comet LINEAR 1999 S4*

10. Saracco P.: *Evolutionary porperties of irregular galaxies*

11. Negueruela, I. (ASI) et al.: *Emission line stras in open clusters: Be or pre-MS?*

12. Pedani M.: *imaging of Ultra steep spectrum sources from the B3.2 survey*

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

14. Marconi, M. et al. (OAN):*Instabilità pulsazionale nella fase di presequenza: pulsano le stelle Herbig Ae?*

15. Polcaro, V.F. (CNR/IAS): *Identification and spectroscopic study of peculiar objects in open clusters*

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

- Application for undergraduate students of astrophysics:

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

- Tests:

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

5.3 Scientific production involving the 152 cm Telescope

1. **Zitelli, V.**, *The brightness and colours of the Loiano sky*, Measuring and Modelling Light Pollution, Cinzano ed., MemSait 2000, 71, 193

2. Polcaro, V.F. et al., *Old spectral type stars in young clusters* , MemSait 2000, in press

3. Polcaro V.F., et al. 2000, *Supernova 2000E in NGC6951*, IAU Circ., vol.7353B, p.1

4. Bernabei S., Marinoni S., Bartolini C., Guarnieri A., Piccioni A., and Masetti N., 2000, *GRB000301C* , GCN 571 (discovery circular)

5. Santangelo et al. 2000, *Supernova 2000BI in anonymous galaxy*, IAU Circ., vol.7398A, p.1

6. Santangelo et al. 2000, *Supernova 2000BI in anonymous galaxy*, IAU Circ., vol.7398A, p.1

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

8. Piccioni A., Bartolini C., Bernabei S., Bruni I., Galleti S., Giovannelli F., Guarnieri A., Sabau-Graziati L., Silvotti R., Ulla A., Valentini G., 2000, *A pulsation episode from the sdB star PG 0856+121*, A&A,354L, 13

9. **Bragaglia, A.**, **Clementini, G.**, **Di Fabrizio, L.**, Di Tomaso, S., **Merighi, R.**, **Tosi, M.**, Ivans, I., Sneden, C., Wilhelm, R., Smith H.A., 2000, *Anomalous pulsation of field RR Lyrae variables: photometric and spectroscopic study of CM Leo, BS Com and CU Com*, in IAU Coll. 176, "The Impact of Large Scale Surveys on Pulsating Stars Research", Eds. L.Szabados & D. Kurtz, ASP Conf.Ser., Vol 203, p. 271

10. Bernabei, S. and Polcaro, V.F. 2001, *A search for peculiar objects in young open clustersI. New emission line and late spectral type stars in NGC6871*, A&A, 366, 817

11. **Clementini, G.**, Di Tomaso, S., **Di Fabrizio**, L., **Bragaglia, A.**, **Merighi, R.**, **Tosi, M.**, Carretta, E., Gratton, R.G., Ivans, I.I., Kinard, A., Marconi, M., Smith, H.A., Wilhelm, R., Woodruff, T., Sneden, C., 2000, *CU Comae: A new field double-mode RR Lyrae, the most metal poor discovered to data*, Astron. J., 120, 2054

12. Masetti N., Bartolini C., Bernabei S., Guarnieri A., Palazzi E., Pian E., Piccioni A., Castro-Tirado A.J., Castro Ceron J.M., Verdes-Montenegro L., Sagar R., Mohan V., Pandey A.K., Pandey S.B., Bock H., Greiner J., Benetti S., Wijers R.A.M.J., Beskin G.M., Gorosabel J., 2000, *Unusually rapid variability of the GRB000301C optical afterglow*, A&A, 359, 23

13. Bernabei S., Polcaro V.F.,2000, *A search for peculiar objects in young open clusters II. A new Be star, the optical counterpart of IRAS 19564+3224 and a new open cluster in Vulpecula (*)*, A&A accepted

14. Bartolini C., Bernabei S., Bruni I., Galleti S. , Giovannelli F., Guarnieri A., Piccioni A., Sabau Graziati L., Silvotti R., Ulla A., Valentini G., 2000, *Open problems in pulsating hot subdwarfs after high speed photometry in Loiano*, SAIT

15. Klose, S., Stecklum, B., Masetti, N., Pian, E., Palazzi, E., Henden, A.A., Hartmann, D.H. Fischer, O., Gorosabel, J., Sánchez-Fernández, C., Butler, D., Ott, Th., Hippler, S., Kasper, M., Weiss, R., Castro-Tirado, A., Greiner, J., Bartolini, C., Guarnieri, A., Piccioni, A., Benetti, S., Ghinassi, F., Magazzú, A., Hurley, K., Cline, T., Trombka, J., McClanahan, T., Starr, R., Goldsten, J., Gold, R., Mazets, E., Golenetskii, S., Noeske, K., Papaderos, P., Vreeswijk, P.M., Tanvir, N., Oscoz, A., Muñoz, J.A., Castro Ceron, J.M., 2000, *The Very Red Afterglow of GRB 000418: Further Evidence for Dust Extinction*, ApJ, 545, 271

16. Bernabei S., Bartolini C., **Di Fabrizio L.**, Guarnieri A., Piccioni A., Masetti N., *GRB 000301C*, GCN 599

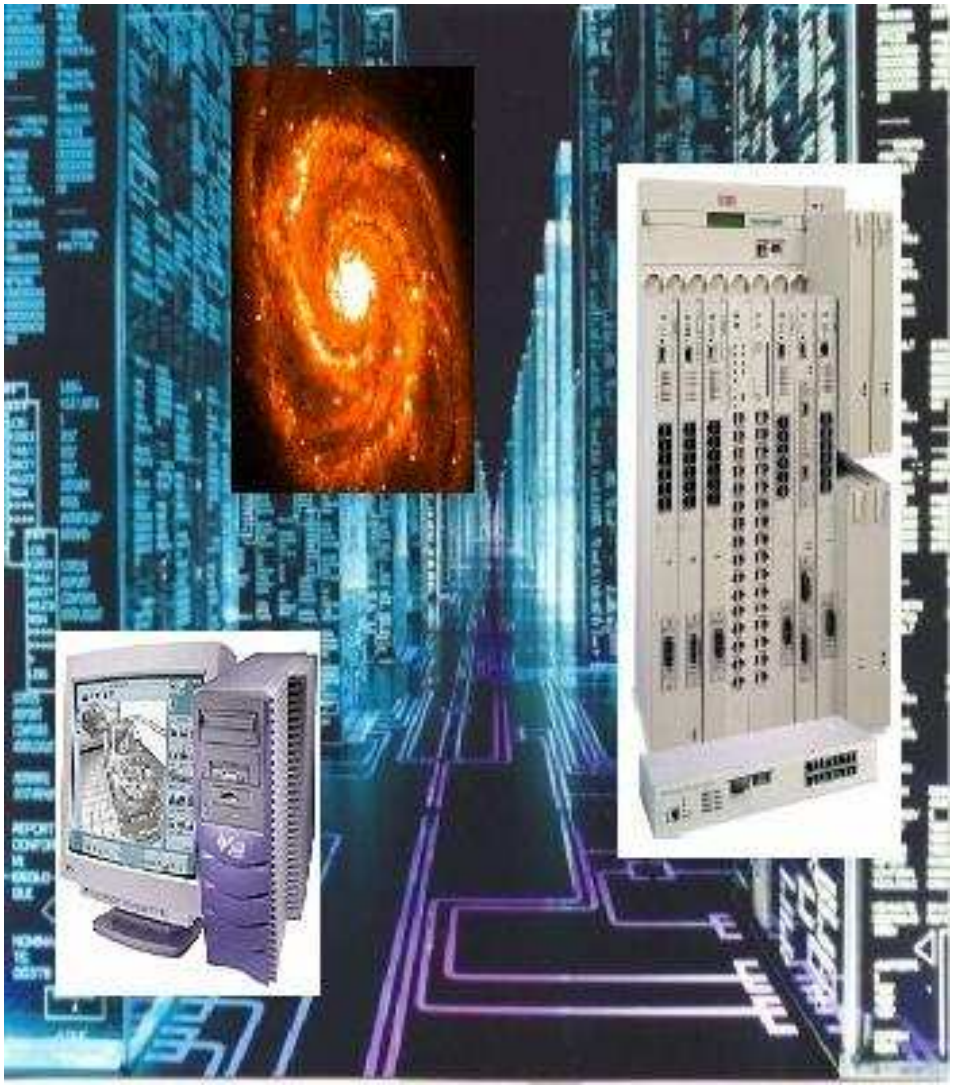
17. Bartolini C., Guarnieri A., Piccioni A., Bernabei S., Covino S., Israel G.L., *GRB 000630*, GCN 737

18. Orlandini M., Parmar A.N., Frontera F., Masetti N., Dal Fiume D., Orr A., Piccioni A., Raimondo G., Santangelo A., Valentini G., Belloni T., 2000, *X-ray/optical observations of XTE J0421+560/CI Cam in quiescence*, A&A, 356, 163

19. Gavazzi G., Bonfanti C., Pedotti P., Boselli A., Carrasco L., 2000,

20. Optical spectroscopy of galaxies in the direction of the Virgo cluster A&AS, 146, 259

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

The main activity of the computer center during year 2000 has been addressed to the improvement of the computer facilities. In particular, the oldest computers have been replaced with newer ones and the same has been done for what concerns storage media and network cards. For what concerns storage space, a new approach has been followed, introducing NAS technology.

6.2 Computer center improvements

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

During 2000 the hardware update of the computer center was continued. Old Alpha workstations were replaced by newer ones or with PCs running Linux OS.

Given the always increasing dimension of astronomical images, the main server (Gemini, Alphaserver 4100, bi-processor) has been doubled in RAM reaching 2 GB of total memory. Also the local disk storage space has been increased.

Two Compaq DS20E were added, to operate on specific projects (VIRMOS group and WFI data reduction).

Disk space has been increased using NAS data storage. Two Quantum Snap Servers 4000 (RAID - 240 GB) and one Snap Server 2100 (RAID - 210 GB) were installed to operate as a storage solution on a work-group base. These devices are configured as RAID 5 system and can be controlled and maintained using a WWW interface.

The pulsar project facility has been improved with the introduction of 4 Compaq Personal Workstation 500, doubling the number of cpus configured as a farm.

The number of PCs used as Unix-Linux workstations increased during 2000 reaching the number of 15 units, plus 10 PCs running Win98. Most of them have been updated with CD-RW and SCSI DAT tapes.

6.3 Improvements in the local network

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

After the installation, in 1999 of the Cabletron switch, all the old computers have been upgraded with network cards working at 100 Mb/s, allowing the network to optimally perform.

A new Cisco router has been added, to directly connect the Observatory network to the GARR back-bone. All the test have been completed and the configuration of the DNS is in progress.

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

The computer in the conference-room has been upgraded and now it is possible to play also DVD and project them with the video-beam. Also the audio equipment of the conference-room have been improved.

6.6 Loiano station

Involved people at OAB: Lolli, Gualandi

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

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, maintenance contracts)
- 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 2000. 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:
  (a) 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).
  (b) 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:* K. Alboresi, M. Ferrarini, M. Marra.

During the year 2000 the "Guido Horn d'Arturo" library[7] has continued to serve its users on similar bases as in the year 1999. The users community has increased, certainly for as much as the students are concerned (according to an official report of the Faculty of Natural Sciences, new enrollments in the Degree course in Astronomy have increased by 23% in recent years). The bibliographic information service (including document delivery and inter-library loan) has remained a well-appreciated service (140 requests have been managed); book acquisitions have increased significantly($\sim$ 220 new books have been cataloged, about 25% more on the whole, compared to 1999), and the high number of library loans (for $\sim$ 700 registered users) shows the importance of books for both students and researchers. The management of serials has concerned about 90 subscription to all the main journals that are relevant to the astronomical research. The ancient books section has been consulted about 40 times; one of Cassini's works ("La Meridiana di S. Petronio", original edition) has been reprinted as a facsimile; other ancient volumes have contributed to two exhibitions in Bologna, one about Luigi Galvani, the other about "Il tempo in ordine".

Both the existing national online catalogues (SBN for books, ACNP for serials), as well as the national online catalogue for astronomical books, "CUBAI", have continued to be updated.

The library has been involved in both the new national projects for Italian astronomical libraries, which have been defined during the astronomy librarians' national congress held in Arcetri in May 2000: (a) the release of a new version of the national opac for astronomical books (CUBAI), and (b) the constitution of a working group on astronomical serials. For both projects, activities have started, have already given results and for some aspects will probably be completed by 2001.

A special initiative has allowed the library to let the national catalogue SBN acquire some hundreds of records that were formerly available only in the local catalogue. Among the online activities, the

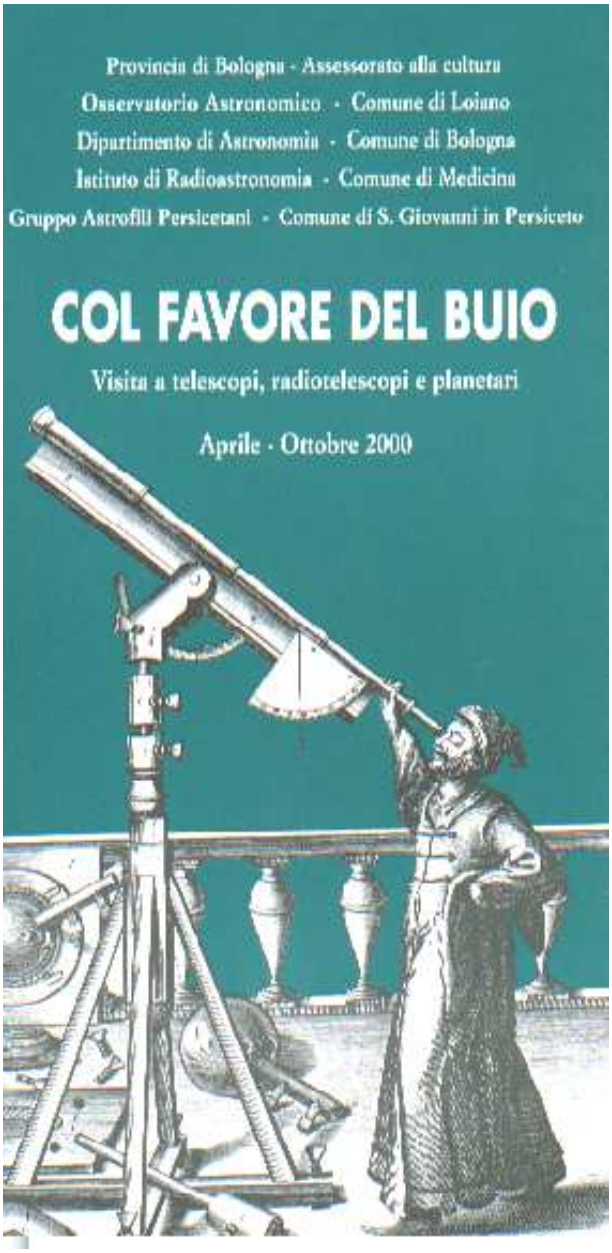
[7] *http://www.bo.astro.it/$\sim$biblio/home.html*

maintaining of the web page of the library and of the online version of the local institutions' scientific preprint list have to be mentioned; on the former resource, in addition to a selection of online catalogues and resources, about 100 online serials are listed, fourteen of which in full-text mode. Other ordinary activities involve the maintaining of the mailing list of loan users; the training of part-time students employed in the library; the attending of professional courses organized by the University of Bologna, as well as serial issues claims and binding.

For as much as the library premises are concerned, an effort was made to improve their usability by installing new orienting signboards in the reading rooms.

As for the staff, Ferrarini left our library in June for a higher position at the University of Bologna; her place was taken in November by Alboresi (ext. contract). The other components of the library staff are still Zuccoli (chief librarian, Dept. of Astronomy), Candelaresi (Dept. of Astronomy) and Marra (OAB).

8 Informative and educational activities



The brochure for the activity COL FAVORE DEL BUIO organized by the Astronomical Observatory of Bologna

Involved people at OAB:

- *Scientific staff*: B. Marano, G. Parmeggiani, V. Zitelli, R. Bedogni, A. Cappi, L. Ciotti, G. Clementini, A. D'Ercole, F.R. Ferraro, F. Fusi Pecci, R. Sancisi, F. Delpino.
- *Technical staff*: A. De Blasi, R. 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 the OAB and other institutions like the Radio astronomic Observatory (CNR Bologna), and the 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:

- Col Favore del Buio
- Leggere il cielo
- IperAstro
- Educational Courses

8.1 Col Favore del Buio

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

The collaboration between the OAB, the Assessorato Provinciale alla Cultura and the Loiano's council lead, 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 modernized, 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 Radio astronomic Observatory of Medicina (BO), the Astronomical Observatory of S. Giovanni in Persiceto (BO), the conference hall of the Bologna Planetarium (primary school G. Carducci) and the Museum of Specola (department of Astronomy). This event has been so 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 Leggere il cielo

People involved at OAB: Parmeggiani.

In 2000 the OAB has organized a new training course for primary and high school teachers. This event, called *Leggere il Cielo*, was sponsored by Bologna's council and managed by Parmeggiani.

This year the event was divided in two corses: *La sfera celeste*, October-Dicember 2000 (with 26 teachers who applied for this course) and *L'universo e l'origine della vita*, February-March 2001 (with 55 teachers enrolled in this course). The astronomy journal of the S.A.It. has published a supplement summarizing these lessons. This article explains very clearly and in a simplistic way the various astronomic topics and it is available to the public. Among the teachers we find the following professors: Bartolini, Bedogni, Bonoli , Cappi, Ciotti, D'Ercole, Marano, Ferraro, Palumbo G., Fusi Pecci, Turricchia , Zitelli.

8.3 IperAstro

People involved at OAB: Bedogni, Delpino.

In collaboration with Zavatti and Delli Santi (Univ. Bologna),

Bedogni and Delpino have realized an Hypertext of Astronomy dedicated to the teachers and students of the advanced Secondary Schools.

The *hypertext* is an electronic text arranged in sections which includes Java applets for better understanding of particular topics. Exercises and tests, with complete solutions and right or wrong answers, respectively, are included to provide a verification in any section in the CD. Written in HTML, *IperAstro* can be accessed using any last generation browser as a network or local (i.e. CD) applications.

The choice of the *hypertext* instrument is important in order to assure the agility of the understanding of the astronomical facts, from the moment that Astronomy itself is *hypertextual*.

To reach this goal, in fact, we require the contribution of information concerning the objects to which the fact belongs, before still increasing our knowledge of any physical and mathematical background.
The structure of the hypertext comprises eight thematic sections:
1-The naked eye sky; 2-The sky with the observation instruments; 3-The Solar System; 4-The Sun; 5-Stars; 6-Galaxies; 7-Cosmology; 8-The Extraterrestrial Life,
and the following tool sections:
1-The physical background; 2-Overall exercises; 3-Tests; 4-Index; 5-Student paths.

Thematic sections are characterized with a content page, including all the links to available pages in the section, followed with a connection to the main content page. Return icons are also available from the starting, the previous and the next page. All sections are equipped with guided exercises and multiple answer tests. Exercises come supplied with useful suggestions for the solution of the problem or also with the complete development of the exercise. The tests show at the end a verification of the supplied answers, in order to let the reader estimate the acquired level of knowledge.

8.4 Educational Course: L'Universo e l'origine della vita

People involved at OAB: Bedogni, Cappi, Ciotti, DErcole, Marano, Ferraro, Fusi Pecci, Zitelli.

Bedogni, Cappi, Ciotti, D'Ercole, Marano, Ferraro, Fusi Pecci and

Zitelli taught in the course it L'Universo e l'origine della vita organized by the Astronomical Observatory of Bologna, in collaboration with the Department of Astronomy of the University of Bologna and the Provincia of Bologna.

9 List of Publications

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203. **Ferraro, F.R.**, **Origlia, L.**, 2000, *Le stelle e la loro evoluzione*, Giornale di Astronomia, 26 (suppl.) n.1, 74

204. **Fusi Pecci, F.**, **Clementini, G.**, 2000, *Globular Clusters*, Enciclopedia of Astronomy and Astrophisics, London, Nature Publishing Group, Institute of Physics Publishing

205. **Marra, M.**, 2000, *New astronomy library in Bologna is named after Guido Horn d'Arturo: a forefather of modern telescopes*, JBAA, 110 n.2, 88

206. **Marra, M.**, *Sorvolando l'Emilia e la Romagna"*, in "Sfoglialibro", luglio-agosto 2000, pp.53

207. **Marra, M.**, *A cavallo di un mouse da Kansas City a Colonia*, in "Sfoglialibro", dicembre 2000, pp.71-72.

208. **Marra, M.**, *Trenta bookmarks per Mary Poppins. Risorse di rete da e per biblioteche destinate ai ragazzi*, in "Sfoglialibro", aprile 2000, pp.58

209. **Zitelli, V.**, 2000, *La radiazione elettromagnetica*, Giornale di Astronomia, 26 (suppl.) n.1, 31

10 Observing Campaigns

Radio Telescopes

1. VLA: PI: **Ciliegi, P.**, Co-I: **Comastri, A.**, C. Vignali, F. Fiore, P. Giommi, A. Antonelli, *6cm radio observations of the HELLAS X-ray sources* 18 hours APRIL 2000.

2. Australia Telescope Compact Array: PI: **Ciliegi, P.**, co-I: **Comastri, A.**, F. Fiore , R. Morganti, F. La Franca, *Radio Observation of Chandra X-ray sources* 24 hours, September 2000.

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

4. Parkes: PI: A.G. Lyne. Co-I:...**D'Amico, N.**, A. Possenti ....; *Multibeam Pulsar Survey*; January term 30 days; May term 20 days; October term 10 days.

5. Parkes: PI: **D'Amico, N.**. Co-I:...A. Possenti...; *Search and timing of pulsars in Globular Clusters*; January term 4 days; May term 6 days; October term 8 days.

6. VLA: PI: R.A. Laing, Co-I: P. Parma, **De Ruiter, H.R.**, A.H. Bridle, R. Fanti; *Decelerating relativistic jets in FRI radio galaxies*; 6 hours May 2000; 1 hour August 2000.

7. VLA: PI: M. Murgia, Co-I: P. Parma, R. Fanti, M. Bondi, **De Ruiter, H.R.**, R.D. Ekers, E.B. Fomalont; *Synchrotron ages of low luminosity radio galaxies*; 4.5 hours, September 2000.

8. VLA: PI: P. Parma, Co-I: A. Capetti, **De Ruiter, H.R.**, R. Fanti, R. Morganti; *8.4 GHz snapshot survey of B2 low luminosity radio galaxies*; 12.5 hours, October 2000.

9. VLA: PI: R. Morganti, Co-I: T. Oosterloo, A. Capetti, P. Parma, K. Wills, **De Ruiter, H.R.**, R. Fanti; *HI absorption lines in FRI radio galaxies*; 7 hours, November 2000; 5 hours, December 2000.

10. Australia Telescope Compact Array: PI: I. Prandoni, CO-I: L. Gregorini, P. Parma, G. Vettolani, **De Ruiter, H.R.**, M.H. Wieringa, R.D. Ekers; *The nature of the faint radio population*; 120 hours, October, November, December 2000.

11. VLA: PI: T. Venturi, co-I: **Bardelli, S.**, et al.; *High resolution observations of extended radio souces in the Shapley Concentration* ; 1 hour, March 2000.ora;

12. VLA: PI: T. Venturi, co-I: **Bardelli, S.**, et al.; *Radio halos and starbursts from violent cluster mergers* ; 4 hours, July 2000.

13. Australia Telescope Compact Array: PI: T. Venturi, co-I: **Bardelli, S.**et al.; *A radio halo candidate in the merging cluster A3562*; 24 hours, January & April 2000.

HST

14. HST: PI: R.E. Schulte-Ladbeck, Co-I: ..., **Greggio, L.**, ...; *Leo A and NGC 6789*; 22 orbits.

15. HST Cycle 10: PI: R. Shaw, Co-I: ..., **Stanghellini, L.**, ...; *Survey of the LMC Planetary Nebulae*; 224 orbits (snapshot).

16. HST Cycle 10: PI: **Stanghellini, L.**; *Planetary Nebulae in the LMC: a study on stellar evolution and Populations*; 28 orbits (prime).

17. HST+WFPC2: PI: **Tosi, M.**, CoIs: **Greggio, L.**, ...; *NGC1705: a benchmark for galaxy evolution*; 18 orbits, September 1999 - November 2000.

18. HST+STIS: PI: C. Leitherer, CoIs: **Greggio, L.**, **Origlia, L.**, **Tosi, M.**, ...; *The α-element/iron ratio in starburst populations*; 18 orbits, April - December 2000.

19. HST+STIS: PI: F. Palla, CoIs: **Stanghellini, L.**, **Tosi, M.**, ..; *The $^{12}C/^{13}C$ abundance ratio in NGC3242*; 5 orbits, March 2001.

ESO

20. ESO 1.5m + FEROS: PI: **Bragaglia, A.**, Co-I: E. Carretta, R.G. Gratton, **Tosi, M.**; *High resolution spectroscopic study of old open clusters as tracers of galactic chemical evolution*; 4 nights, 28/04 - 01/05 2000

21. ESO VLT2 + UVES: PI: R.G. Gratton, Co-I: **Bragaglia, A.**, ..., **Clementini, G.**; *Large programme: Distances, ages, and metal abundances in Globular Cluster dwarfs*; 12 nights, 16-22/06/2000 and 5-11/09/2000.

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

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

24. ESO 1.5m Danish: PI: **Tosi, M.**, Co-I: **Bragaglia, A.**, G. Marconi *Photometry of old open clusters to trace the evolution of the Galactic disk*; 3 nights, May 2001

25. ESO VLT-UT2 + UVES: PI: R.G. Gratton, Co-I: **Bragaglia, A.**, ..., **Clementini, G.**; *Large programme: Distances, ages, and metal abundances in Globular Cluster dwarfs*; 6 nights, 25-31/08/2001.

26. ESO 3.6m: PI: S. Maurogordato, Co-I: M. Arnaud, Batuski, T. Beers, C. Benoist, **Cappi, A.**, C. Ferrari, D. Neumann, R. Pelló, Sauvageot, E. Slezak; *A combined optical/X-Ray program to understand physical processes of formation in a currently merging cluster*; 2.5 nights, December 2000.

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

28. ESO 2.2m + WFI: PI: C. Benoist, Co-I: **Cappi, A.**, C. Ferrari, S. Maurogordato, E. Slezak et al.; *Star Formation within merging Clusters of Galaxies: Multi-Color Imaging*; 1 night, August 2001.

29. ESO VLT: PI: F. La Franca, Co-I: **Comastri, A.**, C. Vignali, F. Fiore, G. Matt, G.Cc Perola, R. Maiolino; *Searching for an hidden AGN in a hard X-ray loud "normal" galaxy*; 0.5 nights, December 2000.

30. ESO 3.6: PI: F. Fiore Co-I: S. Molendi, **Comastri, A.**, C. Vignali, **Mignoli, M.**, G. Matt, F. La Franca, P. Giommi, A. Antonelli, R.

Maiolino, P. Severgnini, M. Elvis, F. Nicastro, M. Cappi; *Assessing the fraction of X-ray loud, optically dull galaxies in Chandra and XMM-Newton surveys*; 3 nights, December 2000.

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

32. ESO 2.2m + WFI: PI: **Ferraro, F.R.**, Co-I: V. Testa, **Origlia, L.**, C. Maraston; *Near Infrared Imaging of Magellanic Cloud Clusters: investigating the Spectral Evolution of Stellar Populations*; 3 nights, 12-14/01/2000.

33. ESO NTT + SUSI2 + EMMI: PI: **Ferraro, F.R.**, Co-I: E. Pancino, L. Pasquini, G. Piotto, **Bellazzini, M.**, M. Zoccali; *Solving the omega Centauri mistery: do the metal rich component belong to a merged cluster?*; 7.8 hours SUSI2, 01/04/2000; 2 nights EMMI 12-13/04/2000.

34. ESO 2.2m + WFI: PI: **Ferraro, F.R.**, Co-I: E. Pancino, B. Paltrinieri, R. Buonanno, R. Rood; *Large Population Studies of Globular Clusters. III*; 3 nights, 6-8/07/2000.

35. ESO VLT + FORS1: PI: **Ferraro, F.R.**, Co-I: V.Testa, G. de Marchi, F. Paresce, L. Pulone, R. Buonanno; *The mass function of intermediate age clusters in the Magellanic clouds: a step toward the determination of the true nature of the IMF*; 12.5 hours, service mode

36. ESO VLT + UVES: PI: E. Pancino, Co-I: **Ferraro, F.R.**, L. Pasquini, **Bellazzini, M.**, V. Hill; *Solving the ω Centauri mistery, a cornerstone in the evolution of stellar systems. III: UVES high-resolution spectroscopy of stars in the anomalous RGB*; 12.5 hours, service mode

37. ESO NTT + SOFI: PI: **Ferraro, F.R.**, Co-I: E. Pancino, **Bellazzini, M.**, T. Richtler, M. Hilker, R.T. Rood; *Solving the ω Centauri mistery, a cornerstone in the evolution of stellar systems. I: Deep high-resolution and IR photometry*; 2 nights, 4-6/05/2001.

38. ESO 2.2m + WFI: PI: I. Saviane, Co-I: E.V. Held, **Clementini, G.**, **L. Di Fabrizio**, Y. Momany; *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.

39. ESO VLT1 + FORS1: PI: **Clementini, G.**, Co-I: E.V. Held, I. Saviane, **L. Di Fabarizio**, Y. Momany, L. Rizzi; *Old populations in the Local Group: the quest for RR Lyrae variables in dwarf galaxies*; 15 hours, service mode.

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

41. ESO VLT1 + ISAAC: PI: E. Oliva, Co-I: A.F.M. Moorwood, **Origlia, L.**, R. Maiolino; *The stellar mass–to–light ratio of Seyferts and the starburst–AGN connection*; 2 nights, 29-30/03/2000.

42. ESO NTT + SOFI: PI: F. D'Antona, Co-I: **Origlia, L.**, E. Oliva, A. Natta, F. Palla; *A search for old, methane-dominated brown dwarfs*; 3 nights, 13-15/05/2000.

43. ESO VLT1 + ISAAC: PI: E. Oliva, Co-I: **Origlia, L.**, F. D'antona, C. Maceroni; *C12/C13 and O16/O17 ratios in O-rich HBB-AGB stars of the Small Magellanic Cloud*; 14 hours, 01/04/2000.

44. ESO 1.5m + FEROS: PI: S. Desidera, Co-I: **Origlia, L.**, **Fusi Pecci, F.**, R. Gratton, E. Carretta, R. Claudi, **Bellazzini, M.**; *Mass loss by giants stars in 47 Tuc: an evolutionary phenomenon or planet engulfing?*; 3 nights, October 2000.

45. ESO 3.6m + TIMMI2: PI: **Origlia, L.**, Co-I: **Ferraro, F.R.**, M. Catelan, R.T. Rood; *Circumstellar dust in Galactic globular clusters: towards an empirical determination of mass loss rates in Population II giants*; 3 nights, 5-8/07/2001.

46. ESO NTT + SOFI: PI: **Origlia, L.**, Co-I: R. Maiolino, R. Cid Fernandez, E. Schmitt, T. Storchi-Bergmann; *Probing the starburst - AGN connection by means of near IR spectroscopy*; 3 nights, 9-13/07/2001.

47. ESO VLT: PI: A. Marconi, Co-I: D. Axon, A. Capetti, K. Horne, A. Robinson, M. Salvati, **Stirpe, G.M.**; *Supermassive black holes in high redshift quasars*; 7.5 hours, July-Sept 2001

48. ESO VLT + UVES: PI: J. Danziger, CoIs: **Tosi, M.**, ...; *A search for ^{3}He in Planetary Nebulae*; 1 night, March 2001

49. ESO 2.2m + WFI: PI : M. Arnaboldi, CoI: D. de Martino, Garilli, L. Guzzo, O. Le Fevre, Maccagni, Mazure, McCracken, Picat, Scaramella, P. Vettolani, **Zamorani, G.**; *A deep + shallow U imaging survey: preparation to the VIRMOS Deep redshift Survey*; 9.8 nights, 5-6/3/2000; 1/5/2000; 22-24/8/2000; 28-31/10/2000; 17-18/11/2000.

50. ESO + ISAAC: PI: A. Cimatti, CoI: A. Renzini, P. Andreani, Daddi, S. di Serego Alighieri, Mannucci, E. Oliva, **Pozzetti, L.**, Rottgering, **Zamorani, G.**; *ISAAC spectroscopy of extremely red galaxies: completion of the sample*; 2 nights, 23-24/3/2000.

51. ESO NTT + SOFI: PI: O. Le Fevre, Co-I: M. Arnaboldi, ..., P. Vettolani, **Zamorani, G.**; *A deep J & Ks imaging survey: preparation to the VIRMOS Deep Redshift Survey*; 3 nights, 25-26/4/2000; 3/9/2000.

52. ESO NTT + SOFI: PI: O. Le Fevre, Co-I: M. Arnaboldi, ..., P. Vettolani, **Zamorani, G.**; *A deep J & Ks imaging survey: preparation to the VIRMOS Deep Redshift Survey*; 3 nights, 4-6/9/2000.

53. ESO NTT + SOFI: PI: O. Le Fevre, Co-I: M. Arnaboldi, ..., P. Vettolani, **Zamorani, G.**; *A deep J & Ks imaging survey: preparation to the VIRMOS Deep Redshift Survey*; 5 nights, 21-25/10/2000.

54. ESO 2.2m + WFI: PI: **Zamorani, G.**, Co-I: **Marano, B.**, **Mignoli, M.**, Hasinger, Lamer; *Mining for Active Galactic Nuclei in the Marano Field: looking for faint color–selected AGN candidates and XMM x–ray sources' counterparts*; 2 nights, 21-22/11/2000.

55. ESO VLT + FORS: PI: A. Cimatti, Co-I: Broadhurst, Cristiani, S. D'Odorico, Daddi, Di Paola, Fontana, R. Gilmozzi, Menci, **Pozzetti, L.**, A. Renzini, P. Saracco, **Zamorani, G.**; *A stringent test on the formation of early type and massive galaxies* Assigned time : 4 nights (24-27/11/2000)

56. ESO - UT2 + ISAAC: *A stringent test on the formation of early type and massive galaxies* PI : Cimatti CoI: Broadhurst, Cristiani, D'Odorico, Daddi, Di Paola, Fontana, Gilmozzi, Menci, Pozzetti, Renzini, Saracco, Zamorani 4 nights, 4-7/12/2000.

57. ESO 3.6 + EFOSC: PI: M. Ramella, co-I: **Bardelli, S.**, **Zucca, E.**et al.; *Spectroscopy of intermediate redshift EIS candidate clusters*; 5 nights, April & September 2000.

58. ESO 2.2m + WFI: PI: M. Ramella, co-I: **Bardelli, S.**et al.; *The luminosity Function of groups of galaxies at z$\sim$ 0.1* ; 10 hours, April-September 2000.

59. ESO NTT + SOFI: PI: M. Scodeggio, co-I: **Bardelli, S.**et al.; *Infrared imaging of distant (z$>$ 0.8) EIS candidate clusters*; 3 notti, January 2001.

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

61. ESO VLT + VIMOS: PI: H. Jorgensen, co-I: **Bardelli, S.**, **Zucca, E.**et al.; *Integral field spectroscopy of optically selected high-z clusters*; 15 hours (service mode).

TNG

62. TNG + OIG/LRS: PI: **Bragaglia, A.**, Co-I: **Tosi, M.**, G. Marconi; *Old open clusters as tracers of the Galactic disk*; 3 different proposals (a) 3 nights January 2000, (b) 3 nights October 2000, (c) 3 nights November 2000.

63. TNG + LRS: PI: **Cacciari, C.**, Co-I: **Bragaglia, A.**, A. Buzzoni, T. Kinman; *RR Lyrae variables at the North Galactic Pole*; 3 nights April 2001.

64. TNG + Arnica: PI: **Clementini, G.**, CoIs: **Cacciari, C.**, **Fusi Pecci, F.**, Di Fabrizio L.; *JK photometry of RR Lyrae variables in M3 and NGC5466*; 4 nights; May 2000

65. TNG: PI: **Clementini, G.**, CoIs: **Cacciari, C.**, **Fusi Pecci, F.**; *The Baade-Wesselink method on RR Lyrae variables in M3*; 3 nights; spring 2001.

66. TNG: PI: C. Vignali, Co-I : **Comastri, A.**, F. Fiore, F. La Franca, F. Nicastro, A. Fruscione, S. Molendi, P. Severgnini, R. Maiolino; 3 half nights, December 2000.

67. TNG + ARNICA: PI: **Ferraro, F.R.**, Co-I: **Origlia, L.**, B. Paltrinieri, E. Oliva, R.T Rood; *Multi-Band population studies of Glactic Globular Clusters: Infrared Luminosity Functions*; 4 nights, 10-13/05/2000.

68. TNG + DOLORES + NICS: PI: **Ferraro, F.R.**, Co-I: **Bellazzini, M.**, **Cacciari, C.**, **Origlia, L.**, E. Pancino, E. Oliva; *Getting accurate distances to Local Group galaxies*; 3 nights LRS 19-22/03/2001; 3 nights NICS (service mode) April 2001.

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

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

Loiano

71. Loiano – 1.52m: PI: **Bragaglia, A.**, Co-I: E. Carretta; *The colour magnitude diagram of the globular cluster M56*; 2 nights, August 2000.

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

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

BeppoSAX

74. BeppoSAX: PI: C. Vignali, Co-I: **Comastri, A.**; *Unraveling the intrinsic X-ray emission from the Seyfert 2 galaxy NGC 3281*; 100.000 sec, May 2000.

75. BeppoSAX: PI: G. Malaguti, Co-I: L. Bassani, M. Cappi, E. Caroli, **Comastri, A.**, G. Di Cocco, F. Frontera, A. Malizia, C. Vignali; *BeppoSAX observations of poorly studied Piccinotti sources: towards completing the entire sample*; 200.000 sec, May 2000.

76. BeppoSAX: PI: L. Bassani, Co-I: G. Malaguti, M. Cappi, **Comastri, A.**, M. Dadina, D. Dal Fiume, G. Di Cocco, A. Fabian, F. Frontera, M. Guainazzi, G. Palumbo, P. Blanco, L. Piro, M. Trifoglio; *Unraveling the intrinsic X-ray emission from the Seyfert 2 galaxy NGC 3281*; 200.000 sec, May 2000.

77. BeppoSAX: PI: **Bardelli, S.**, Co-I: **Zucca, E.**, **Zamorani, G.**et al.; *Thermal-chemical-shock structure in supercluster* 250.000 sec, January 2000.

78. BeppoSAX: PI: **Bardelli, S.**, Co-I: **Zucca, E.**et al.; *A3560: A Cluster at the Edge of a Major Merging* 70.000 sec, July 2000.

79. BeppoSAX: PI: S. De Grandi, Co-I: **Bardelli, S.**, **Zucca, E.**et al.; *The dynamics of merging clusters in Cor Bor supercluster* 250.000 sec, August 2000 & January 2001

CHANDRA

80. Chandra: PI: G. Brunetti, Co-I: **Comastri, A.**, G. Setti; *Inverse Compton scattering in quasar radio lobes and the spectrum of relativistic electrons*; 90.000 sec, December 2000.

81. Chandra: PI: S. Pellegrini, Co-I: **Comastri, A.**, G. Fabbiano, F. Fiore, R. Morganti, G. Trinchieri, T. Venturi, C. Vignali; *Origin of the hard emission in the optically inactive elliptical galaxy IC 4296 from high resolution X-ray and radio observations*; 25.000 sec, May 2001.

Miscellaneous

82. CFHT 3.6m: PI: S. Maurogordato, Co-I: **Cappi, A.**, E. Slezak; *Deep Multicolor Field Imaging of A521*; 1 night, January 2000.

83. DBS + 2.3m MSSSO: PI: J. Norris, Co-I: **Ferraro, F.R.**, E. Pancino; *The metal-rich population of ω Cen*; 3 nights, 25-28/02/2001.

84. AZT-24, 1.2m Campo Imperatore: PI: F. Caputo, CoIs: G. Bono, ..., **Cacciari, C.**, **Clementini, G.**, ..., **L. Di Fabrizio**, ...; *Large Program: Evolutionary and Pulsation Properties of Radial Variables*; 10 nights, first three 22-24/05/2000.

85. KeckII + NIRSPEC: PI: R.M. Rich, Co-I: S.M. Castro, **Origlia, L.**; *Abundances of Bulge and Galactic Center cluster stars*; 2 nights, 22-23/06/2001.

86. XMM: PI: S.Ettori, Co-I: **Bardelli, S.**, **Zucca, E.**et al.; *Spatially resolved spectroscopy of merging clusters in the Shapley Concentration* 45.000 sec, 2000/2001

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 & Teacher for "Dynamical models in Astrophysics", academic year 2000-2001.

- **Comastri, A.**:
  - Astrophysics working group (XAWG) for XEUS (ESA mission): member
  - Bologna University: teacher of "Space Physic", academic year 2000-2001

- **Ferraro, F.R.**:
  - ESO: Visting Astronomer
  - ST-ECF User Committee: member
  - ESA panel *Galactic* for HST time allocation (cycle 10): member
  - TNG time allocation (2000-2001): external referee
  - OAB team ITAL-FLAMES Consortium: member
  - Bologna University: teacher of "Stellar Evolution", academic year 2000-2001

- **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.**:
- CNAA: member of the Board and of the executive committee
- LBT Scientific Advisory Committee: member, chairperson until Aug. 30
- LUCIFER (IR LBT instrument) Review Board: chairperson
- Bologna Astronomical Observatory: director and member of the Board

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

- **Stanghellini, L.**:
- ESA/STScI: associate astronomer in the Scientific Directorate (1998-present)
- Science Recruitment Committee at STScI (2000-2001): member
- Institute Fellowship Search Committee (2001): member
- PhD Thesis committee, Ms. Eva Villaver, IAC (graduation: April 2001): member

- **Tosi, M.**:
- TNG: external referee for the Time Allocation Committe
- Working group *Local Late Galactic Evolution* at the ESA International Space Science Institute (Bern): member
- Working group for the NASA mission *Interstellar Pathfinder*: member

- **Zamorani, G.**:
- ESO : VIRMOS Science Team (approved instrument for VLT): member

- ESO: Survey Working Group: member
- SAX: Science Steering Committee (1999 - 2001): member
- Bologna Astronomical Observatory: member of the Board - Arcetri Astrophysical Observatory: member of the Board.

- **Zitelli, V.**:
  - "Site testing" TNG committee: member
  - person in charge of Loiano telescopes

- **Zucca, E.**:
  - member of the SOC and chair of the LOC for the "XLV Congresso Nazionale della Società Astronomica Italiana"

12 Colloquia and visiting astronomers

1. January 13, 2000: **Stefano Ettori** (Institute of Astronomy, Cambridge, UK) *"Incertezze nella misura della temperatura del gas degli ammassi di galassie"*

2. January 20, 2000: **Lourdes Verdes-Montenegro** (Istituto de Astrofisica de Andalucia, Granada, Spagna) *"What HI tell us on compact groups of galaxies"*

3. January 27, 2000: **Andrea Possenti** (Dipartimento di Astronomia, Università di Bologna) *"Stelle di neutroni riaccelerate in sistemi binari: il periodo P=1.56 ms è una barriera invalicabile?"*

4. February 3, 2000: **Alvio Renzini** (European Southern Observatory) *"Il VLT: stato del programma e primi risultati scientifici"*

5. February 17, 2000: **Roberto Della Ceca** (Osservatorio Astronomico di Brera) *"La ASCA Hard Serendipitous Survey (HSS)"*

6. February 24, 2000: **Domenico Bonaccini** (European Southern Observatory) *"Ottiche Adattive all'ESO: dalla correzione del tip-tilt alle stelle di guida laser"*

7. march 2, 2000: **Eugenio Carretta** (Osservatorio Astronomico di Padova) *"Abbondanze in stelle di Pop.II come test dei modelli di evoluzione stellare: risultati e prospettive"*

8. March 9, 2000: **Francesca Matteucci** (Dipartimento di Astronomia, Università di Trieste) *"L'evoluzione delle galassie irregolari nane"*

9. March 16, 2000: **Jan Brand** (Istituto di Radioastronomia, CNR, Bologna) *"Ricerca di protostelle di grande massa"*

10. March 20, 2000: **Riccardo Giovanelli** (Department of Astronomy, Cornell University, U.S.A.) *"On the Convergence Depth of the Local Universe"*

11. March 21, 2000: **Martha Haynes** (Department of Astronomy, Cornell University, U.S.A.) *"Kinematic Evidence of Minor Mergers in isolated Sa Galaxies"*

12. March 23, 2000: **Paul Schechter** (Massachusetts Institute of Technology, U.S.A.) *"Fermat's principle, gravitational mirages, and Hubble's constant"*

13. April 6, 2000: **Maurizio Busso** (Osservatorio Astronomico di Torino) *"Evoluzione e nucleosintesi stellare nelle fasi AGB"*

14. April 13, 2000: **Marc Verheijen** (NRAO, Socorro, U.S.A.) *"An HI study of the Ursa Major cluster of galaxies"*

15. April 18, 2000: **Barbara Lanzoni** (Institut d'Astrophysique de Paris, France) *"Formazione delle galassie negli ammassi"*

16. April 27, 2000: **Lucia Pozzetti** (Osservatorio Astronomico di Bologna) *"Ricerca di galassie ad alto redshift nell'ottico e nel vicino infrarosso"*

17. May 2, 2000: **Joel Bregman** (Dept. Astronomy, University of Michigan, U.S.A.) *"New views of cooling flows"*

18. May 4, 2000: **Claudio Firmani** (Instituto de Astronomia, Universidad Nacional Autonoma de Mexico & Osservatorio Astronomico di Brera) *"Struttura, dinamica ed evoluzione delle galassie di disco nello scenario di formazione gerarchico"*

19. May 11, 2000: **Ignas Snellen** (Institute of Astronomy, Cambridge, UK) *"Young radio-loud AGN"*

20. May 18, 2000: **Domenico Bonaccini** (European Southern Observatory) *"Ottiche Adattive all'ESO: dalla correzione del tip-tilt alle stelle di guida laser"*

21. May 25, 2000: **Francesco R. Ferraro** (Osservatorio Astronomico di Bologna) *"Evidenze osservative di collisioni stellari e merging negli ammassi globulari"*

22. June 1, 2000: **Roberto Ragazzoni** (Osservatorio Astronomico di Padova) *"Ottica adattiva a largo campo per telescopi da 8 a 100m di diametro"*

23. June 8, 2000: **Sergio Campana** (Osservatorio Astronomico di Merate) *"X-ray transients in quiescence"*

24. June 13, 2000: **Piero Madau** (Institute of Astronomy, Cambridge, UK) *"Cosmological Reionization and the End of the Dark Ages"*

25. June 20, 2000: **Piet van der Kruit** (Kapteyn Astronomical Institute, Groningen, NL) *"Stellar velocity dispersions and stability in disks of spiral galaxies"*

26. June 22, 2000: **Marco Chiaberge** (SISSA, Trieste) *"I nuclei delle radiogalassie visti da Hubble Space Telescope"*

27. June 29, 2000: **Giuseppe Bertin** (Scuola Normale Superiore, Pisa) *"Misure di massa senza dinamica"*

28. July 11, 2000: **Ron Allen** (STScI, Baltimore, USA) *1) "Crowded-Field Astrometry and Imaging with the Space Interferometry Mission" 2) "Cold Molecular Gas, PDRs and the Origin of HI in Galaxies: HI as a tracer for Molecular Hydrogen"*

29. October 3, 2000: **Tommaso Treu** (Scuola Normale Superiore, Pisa) *"On the formation and evolution of early-type galaxies"*

30. October 12, 2000: **Tjeerd van Albada** (Kapteyn Astronomical Institute, University of Groningen, NL) *"Mergers and the fundamental plane of elliptical galaxies"*

31. October 19, 2000: **Pieter van Dokkum** (California Institute of Technology, Pasadena, USA) *"Formation and evolution of early-type galaxies: young galaxies containing old stars"*

32. October 26, 2000: **Massimo Cappi** (Istituto TeSRE, CNR, Bologna) *"Studio delle sorgenti X rivelate da Chandra intorno a due ammassi di galassie distanti ($z\sim0.5$)"*

33. November 9, 2000: **Francesco Palla** (Osservatorio Astrofisico di Arcetri) *"Accelerazione della formazione stellare in ammassi e associazioni"*

34. November 14, 2000: **Vera Rubin** (Dept. of Terrestrial Magnetism, Carnegie Institution of Washington, USA) *"Kinematically Disturbed Spirals in the Virgo Cluster"*

35. November 23, 2000: **Paolo De Bernardis** (Dipartimento di Fisica, Università La Sapienza, Roma) *"Archeologia dell'universo con l'esperimento BOOMERanG"*

36. November 30, 2000: **Isabella Prandoni** (Dipartimento di Astronomia, Università di Bologna & Istituto di Radioastronomia del CNR, Bologna) *"La survey radio ATESP ed il suo follow-up ottico"*

37. December 7, 2000: **Carlotta Gruppioni** (Osservatorio Astronomico di Padova) *"ISOCAM Extragalactic Mid-Infrared Source Counts from the ELAIS Survey"*

38. December 14, 2000: **Grigori Beskin** (Special Astrophysical Observatory, Caucaso) *"New possibilities of the galactic black holes detection"*

39. December 19 2000: **Maurizio Toscano** (The University of Melbourne, Australia) *"A Study of Southern Millisecond Pulsars"*

40. December 21, 2000: **Alessandra Aloisi** (STScI, Baltimore, USA) *"Galassie nane con formazione stellare nell'Universo locale: HST svela i segreti della loro storia evolutiva"*

13 "Laurea" thesis at the Bologna Observatory

March 20, 2000:

1. **Adamo Angelo**, *Proprietà statistiche della distribuzione delle galassie* (Battistini P., **Cappi, A.**)

2. **Boccalini Natascia**, *Un database di variabili RR Lyrae consultabile in modo interattivo* (Bonoli F., **Clementini, G.**)

3. **Di Lorenzo Pierluigi**, *Una rassegna delle maggiori pulsar surveys* (Fanti R., **D'Amico, N.**)

4. **Di Tomaso Simona**, *La variabile RR Lyrae CU Comae* (Bonoli F., **Clementini, G.**)

5. **Melandri Fabrizio**, *Determinazione della distanza di due RR Lyrae di campo con il metodo di Baade-Wesswlink* (**Marano, B.**, **Cacciari, C.**, **Clementini, G.**)

6. **Melioli Claudio**, *Efficienza di supernovae nell'energetica in regioni di intensa formazione stellare* (**Marano, B.**, **D'Ercole, A.**)

7. **Nigro Francesco**, *Osservazione di scintillazione di una nuova millisecond pulsar* (Gregorini L., **D'Amico, N.**, Nicastro)

July 17, 2000:

8. **Lanzi Roberto**, *La galassia di Seyfert NGC 4507: osservazioni multiple a banda larga con il satellite BeppoSax* (**Marano, B.**, **Comastri, A.**)

9. **Lumiella Vincenzo**, *Parametri di scintillazione per un campione di pulsar osservate con il radiotelescopio di Parkes* (Gregorini L., **D'Amico, N.**, Nicastro)

10. **Muccione Veruska**, *Risonanze orbitali in sistemi non collisionali: applicazioni a galassie ellittiche in ammasso* (Setti G., **Ciotti, L.**)

October 16, 2000:

11. **Bernardi Gianni**, *Analisi degli ammassi globulari M80 e NGC 288 col codice Starfinder: simulazioni test e confronto con risultati pubblicati* (Bendinelli O., **Ferraro, F.R.**)

12. **Braida Michela**, *Sistemi tripli di galassie: un approccio statistico* (Focardi P., **Zitelli, V.**)

13. **Brusa Marcella**, *Il contributo dei nuclei galattici attivi al fondo infrarosso e submillimetrico* (**Marano, B.**, **Comastri, A.**)

December 18, 2000:

14. **Burgay Marta**, *Ricerca di pulsazioni radio in sorgenti X transienti* (Fanti R., **Possenti A.**, **D'Amico, N.**)

15. **Colucci Samantha**, *Ricerca di stelle variabili RR Lyrae nell'ammasso globulare M54* (Battistini P., **Bellazzini, M.**, **Cacciari, C.**)

16. **Monaco Lorenzo**, *Popolazioni di sistemi binari in ammassi globulari: il caso di NGC 288* (Battistini P., **Bellazzini, M.**, **Fusi Pecci, F.**)

17. **Ranalli Piero**, *Emissione di alta energia da galassie starburst* (Setti G., **Comastri, A.**)

18. **Sabbi Elena**, *Le popolazioni stellari nella galassia nana NGC 1705* (Bonoli F., **Tosi, M.**)

19. **Zagaria Michele**, *Osservazioni radio di ammassi di galassie interagenti. La catena A3571 - A3572 - A3575* (Fanti R., **Bardelli, S.**, Venturi T.)

14 PhD theses at the Bologna Observatory

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

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

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

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

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

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

15 Post-Doctoral, Post-Laurea fellowship and Contracts

1. **Luca Di Fabrizio** Post Laurea contract, completed

2. **Silvia Galleti**, Post Laurea fellow, completed

3. **Andrea Possenti**, Post-Doctoral fellow, in progress

4. **Emanuel Rossetti**, contract, in progress