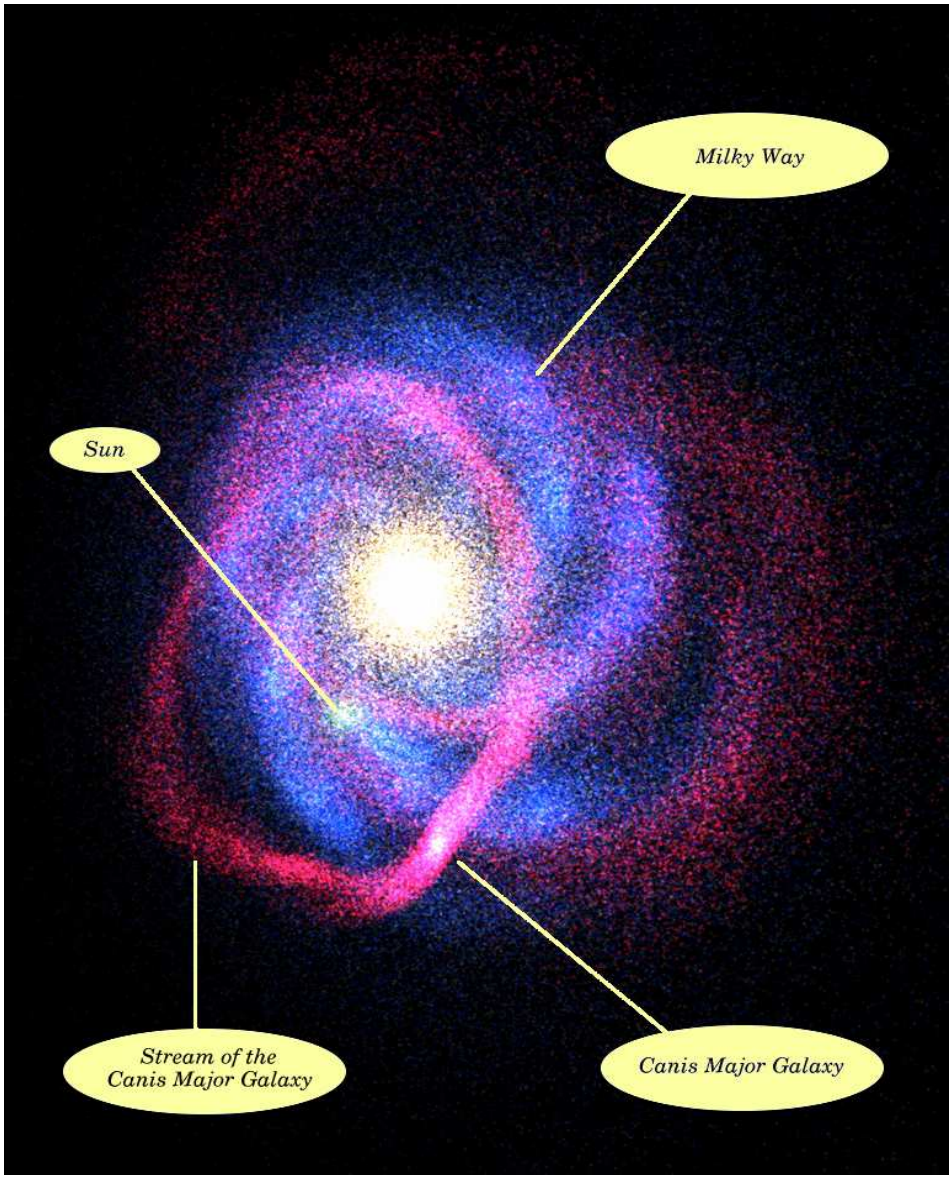
Milky Way
Sun
Stream of the
Canis Major Galaxy
Canis Major Galaxy

INAF

Osservatorio Astronomico di Bologna

Annual Report 2003

Osservatorio Astronomico di Bologna
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Cover: The tidal forces of the Milky Way slowly pull apart the Canis Major (CMa) dwarf galaxy (shown here in red). The stars ripped off in this fashion surround the galaxy in a vast ring. The red points are from the N-body simulation of the CMa relic that best fit the existing data (Martin et al. 2004, MNRAS 348, 12). In blue: an artist's view of the Milky Way galaxy, to sketch the relative positions of the CMa galaxy and its stream and the Galactic disk. The discovery of the CMa galaxy has been announced on November 2003 with a joint press release of the Royal Astronomical Society (UK), INAF-OAB (Italy), Observatoire de Strasbourg (France). Credit: N. Martin, R. Ibata, M. Bellazzini, M.J. Irwin, G.F. Lewis, W. Dennen.

Presentation

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

This Report gives an overview of our scientific researches, covering a wide range of astrophysical topics, as well as operational and educational activities. OAB astronomers are mostly involved in:

- studies of stellar populations and galactic evolution and their cosmological implications;
- studies of the structure, evolution and distribution of galaxies, clusters and AGNs, and their contribution to the cosmological backgrounds;
- numerical studies in the field of gas hydrodynamics and turbulence simulations;
- 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.
- outreach and educational initiatives, through exhibitions, lectures and workshops.

Most of these studies are based on an intensive use of the most advanced instruments available today at all wavelengths. They 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)*. A large fraction of the staff is involved in international long-term projects.

A very schematic summary of the Observatory budget in 2003 is presented (in Italian) at the end, for administrative purposes.

This report has been prepared by Alberto Buzzoni, Alberto Cappi, Antonio De Blasi, Annibale D'Ercole, Monica Marra, Roberto Merighi, Gianluigi Parmeggiani, Giovanna Stirpe, Monica Tosi and Valentina Zitelli.

Flavio Fusi Pecci

(Director)

Osservatorio Astronomico di Bologna: 2003

- *Director:* Flavio Fusi Pecci
- *Deputy Director:* Monica Tosi
- *Board:* Flavio Fusi Pecci (chair), Sandro Bardelli, Michele Bellazzini, Bruno Marano, Renzo Sancisi, Franco Tinti, Valentina Zitelli.

Staff

- *Scientific Staff:* Bardelli, Sandro; Bedogni, Roberto; Bellazzini, Michele; Bonifazi, Angelo; Bragaglia, Angela; Buzzoni, Alberto (on temporary assignement since September 2003); Cacciari, Carla; Cappi, Alberto; Ciliegi, Paolo; Clementini, Gisella; Comastri, Andrea; Delpino, Federico; D'Ercole, Annibale; De Ruiter, Hans; Federici, Luciana; Fusi Pecci, Flavio; Londrillo, Pasquale; Merighi, Roberto; Mignoli, Marco; Origlia, Livia; Parmeggiani, Gianluigi; Pozzetti, Lucia; Sancisi, Renzo; Stanghellini, Letizia; Stirpe, Giovanna; Tosi, Monica; Zamorani, Gianni; Zitelli, Valentina; Zucca, Elena
- *Computer Centre:* Di Luca, Roberto; Gatti, Michele; Lolli, Marco; Madama, Guido; Montegriffo, Paolo; Policastro, Rocco
- *Laboratory:* Bregoli, Giovanni; Ciattaglia, Costantino; Innocenti, Giancarlo
- *Technical Services:* Tinti, Franco; Ravaglia, Maurizio
- *Loiano Staff:* Bernabei, Stefano; Bruni, Ivan; De Blasi, Antonio Gualandi, Roberto; Mezzini, Rino (until August 1st, 2003); Muzi, Ivo; Salomoni, Paolo
- *Administration:* Greganti, Andrea; Abicca, Renata; Caiulo, Alessandro; Diodato, Olga; Orlandi, Marco; Pavan, Claudia; Piccioni, Annalia; Polastri, Tiziana; Venturini, Adele
- *Library:* Marra, Monica; Alboresi, Katia (ext. contract)
- *Reception:* Caputo, Silvana; Iuso, Annalisa

PhD, fellows and contracts:

- *PhD students with OAB supervisors:* Angeretti, Luca; Baldacci, Lara; Brusa, Marcella; Galleti, Silvia; Marcolini, Andrea; Monaco, Lorenzo; Ranalli, Piero; Sollima, Antonio; Valenti, Elena.

- *Post-doc:* Lanzoni, Barbara; McCracken, Henry; Pancino, Elena; Possenti, Andrea; Romano, Donatella; Vignali, Christian.

- *Fellows and contracts:* Beccari, Giacomo; Calabrese, Emanuela; Civano, Francesca Maria; De Simone, Erika; Fraternali, Filippo; Giacintucci, Simona; Greco, Claudia; Lombini, Marco; Maio, Marcella; Marini, Francesca; Marinoni, Silvia; Nardinocchi, Ilario; Rossetti, Emanuel; Vocale, Matteo.

Contents

1 Stars and Stellar Populations

The central region of the dwarf starburst galaxy NGC1705 as seen by the Hubble Space Telescope. At a distance of 5.1 Mpc, most of the individual stars of NGC 1705 are out of range of all but the sharp eyes of HST. The bright concentration at the galaxy center is a Super Star Cluster. From these data, the star formation history of the galaxy has been derived at the INAF – Bologna Observatory. Image Credit: Tosi, NASA, ESA and the Hubble Heritage Team.

People involved at OAB:

- *Scientific staff:* M. Bellazzini, A. Bonifazi, A. Bragaglia, A. Buzzoni, C. Cacciari, G. Clementini, L. Federici, F. Fusi Pecci, L. Origlia, G. Parmeggiani, L. Stanghellini, M. Tosi;
- *Technical staff:* M. Lolli, P. Montegriffo;
- *Fellows:* L. Baldacci, S. Galleti, M. Maio, L. Monaco, E. Pancino, A. Possenti, D. Romano, E. Rossetti, E. Valenti.

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

The present description of the activity in the year 2003 has been organized in a few main sections to provide a very general overview: 1. The Galaxy, 2. Globular clusters, 3. Nearby Galaxies, 4. Population Synthesis, 5. Pulsating Variable stars, 6. Eclipsing binaries, 7. Planetary Nebulae.

1.1 The Galaxy

1.1.1 Chemical evolution models

People involved at OAB: Romano, Tosi.

Models of Galactic chemical evolution are nowadays able to reproduce the vast majority of the observed characteristics of our Galaxy. There are, however, a number of open questions on the evolution of the Galaxy, which still require further studies (e.g. Tosi 2003c). Some of these issues are being examined in detail at the Bologna Observatory. In 2003, we have proceeded in the effort of accurately analysing the feedback between stellar and chemical evolution, the evolution of the abundance gradients and the impact of Galactic chemical evolution models on cosmology. To this aim, new models for D, ^3He, ^4He, ^{12}C, ^{13}C, ^{14}N, ^{16}O, ^{17}O, ^{18}O, ^{20}Ne, ^{22}Ne and heavier species up to Fe have been computed and compared with the available data, adopting all the most recent and reliable stellar yields, IMF and stellar lifetimes. The role of novae has also been studied in detail. These binary systems

have long been recognized to be able to produce peculiar elements with large overproduction factors during outbursts (José and Hernanz 1998 and refs. therein). Accounting for that in the chemical evolution code allows us to explain fairly well the evolution of ^7Li and some of the CNO isotopes (Romano and Matteucci 2003).

A collaboration exists with the International Space Science Institute in Berne (Switzerland) to study all the aspects of stellar and galactic evolution affecting the abundances of the light elements. All the Galactic chemical evolution models able to reproduce the largest set of observational constraints have shown that the primordial abundance of D and ^3He must have been fairly low. This implies that the baryon/photon ratio was fairly high during the Big Bang, a result emphasized by the MAXIMA and BOOMERANG, and most recently WMAP, experiments on the cosmic microwave background. Our group has shown (Romano et al. 2003) that the primordial abundances of the light elements resulting from the WMAP data are in excellent agreement with the predictions of those among our chemical evolution models which best reproduce the galactic properties. This result is interesting in many respects. Indeed, it shows that the predictions of the standard theory of Big Bang nucleosynthesis, updated theories of galactic and stellar formation and evolution as well as the most recent observational inferences on the primordial element abundances can be all gathered together in a single, common, coherent evolutionary scenario.

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

People involved at OAB: Bonifazi, Bragaglia, Tosi.

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

In order to study in more detail the metallicity and age distribution with galactocentric distance, we are analyzing with great accuracy a large sample of open clusters (our goal is to have at least 30 OC's) at various Galactic locations and covering a wide range in age and metallicity. Age, distance modulus, reddening and approximate metallicity of the clusters are derived from their Color-Magnitude Diagrams (CMDs) using the synthetic CMD technique, developed by Tosi at the OAB, and further constrained by the observed luminosity functions. Precise and homogeneous elemental abundances are determined from high resolution spectroscopy.

During 2003, we have published our findings on Cr 110 (Bragaglia & Tosi 2003), completed the interpretation of NGC 6939 in terms of evolutionary parameters (Andreuzzi et al. 2004) and proceeded in that of Be 29 (Tosi et al., submitted in 2004).

Up to now only about 25 % of the $\sim$ 80 old OC's have ever been studied with high resolution spectroscopy, and only a handful have abundances of elements other than iron. To widen the sample, we have obtained high-res spectra of red clump stars in a dozen of OC's, with FEROS@1.5m ESO, SARG@TNG, and UVES@VLT. Three clusters have been analyzed and published (NGC 2506, NGC 6134, IC 4651; Carretta et al. 2004). Furthermore, FLAMES@VLT GTO observations have been completed (3 nights, PI Pallavicini, OAPa) for three more old clusters (Cr 261, Mel 66, and NGC 2506), and a proposal to observe 10 more open clusters has been approved, also on FLAMES@VLT (in collaboration with S. Randich et al.).

Finally, medium resolution spectra for 20 stars in Be 29 have been obtained with MOS@TNG, and membership based on radial velocity has been determined (Bragaglia, Held & Tosi 2004).

This research is in collaboration with Carretta, Gratton, Held (INAF–Padova Obs.), Marconi and Andreuzzi (INAF–Roma Obs.), Randich (INAF–Arcetri Obs.), Carraro (Padova Univ.) and Pallavicini (INAF–Palermo Obs.).

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

People involved at OAB: Bragaglia, Buzzoni, Cacciari.

Field BHB stars and RR Lyrae variables are excellent tracers of the galactic halo stellar population. A detailed knowledge of their chemi-

cal and dynamical characteristics is therefore essential to understand how the Galaxy formed (e.g., hierarchical accretion/merging processes).

The questions of whether the high Galactic halo is in retrograde rotation and how the velocity dispersion and flattening of the halo vary with height above the Galactic plane are still controversial. They could be settled by studying halo stars nearer than about 10 kpc. In collaboration with Kinman (NOAO, USA) and Spagna (INAF–OATo) we are studying a sample of about 150 BHB and RR Lyrae stars near the North Galactic Pole by means of radial velocities and GSC-II proper motions for which we were granted a GSC-II pilot-program. Metallicities are estimated from various methods.

Photometric and spectroscopic data were collected during the last years; in particular spectra were collected in spring 2001, 2002 and 2003 (SARG@TNG, LRS@TNG). Results on the space motions based on about half of our data show that our sample is distinctly retrograde (Kinman et al. 2003, Cacciari et al. 2003).

A new field (towards the Anticenter) has been proposed in 2003, also with LRS@TNG, and observations of BHB stars have been obtained in January 2004.

1.2 Globular Clusters

1.2.1 Observational tests of theoretical stellar models

People involved at OAB: Bellazzini, Fusi Pecci, Origlia, Pancino, Sollima, Valenti

Stellar evolutionary models are often used to derive relevant properties of globular star clusters and galaxies, such as their age and metal content. The Luminosity Function of the stellar sequences in the CMDs, from the MS Turn Off (TO) up to the termination of the Asymptotic Giant Branch (AGB), has been recognized to be the most powerful tool 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 infrared observations to measure the cool Red Giant Branch (RGB) stars and UV observations to properly study the blue sequences as the Horizontal Branch and the Blue Stragglers.

This year a major work on the calibration of the RGB features by using the IR photometric database of Galactic globular clusters (GGCs) collected by our group over the last 5 years has been performed, in collaboration with F. Ferraro (University of Bologna), O. Straniero (INAF–OA Teramo), R.T. Rood (University of Virginia, USA).

By analyzing the color-magnitude diagrams of 24 bulge and halo GGCs a set of photometric indices describing the morphology (i.e. slope) and the location in color and in magnitude of the RGB has been measured and calibrated as a function of the cluster metallicity in all the available IR bands (Valenti et al. 2004). The major RGB evolutionary features, namely the RGB bump and tip, have been also measured and calibrated with varying cluster metallicity (Valenti et al. 2004; Bellazzini et al. 2004). An overall good agreement with the predictions of the most recent models of stellar evolution has been found. The RGB "bump" and tip represent powerful tools to obtain independent estimates of the metalicity and distance, respectively, in old stellar systems within the Local Group. The new IR adaptive optics facilities available at ground-based 8m-class telescopes as well as the future imaging capabilities of the James Webb Space Telescope will allow to use the RGB tip as a distance indicator in galaxies well beyond the Local Group, up to several Mpc away. An empirical calibration of the mixing-length theory and a new method to derive reddening and metallicity estimates, based on this database, are still in progress.

The IR spectral range is also particularly suitable to study the mass loss process in giant stars. Mass loss is a crucial parameter in any stellar evolution modeling. The late evolutionary stages of low- and intermediate-mass giant stars are strongly influenced by mass loss processes. Yet, our lack of empirical estimates on mass loss in low-mass RGB and AGB stars remains one of the most serious stumbling blocks for a comprehensive understanding of stellar evolution. A deep survey of the very central regions of six massive globular clusters has been performed using ISOCAM in the 10 μm spectral region (Origlia et al. 2002). From a combined physical and statistical analysis we derived mass loss rates and frequency. We find that *i)* significant mass loss (at rates in the range $10^{-7} < dm/dt < 10^{-6} m_{\odot}$ yr^{-1}) occurs

only at the very end of the RGB evolutionary stage and is episodic, *ii)* the modulation timescales should be shorter than 1 million years, and *iii)* mass loss occurrence does not show a crucial dependence on the cluster metallicity. A follow-up program using the NASA Spitzer Space Telescope has been proposed for Cycle 1 observations.

1.2.2 Main Sequence Fitting Distances and absolute ages of Galactic globular clusters

People involved at OAB: Bragaglia, Clementini, Fusi Pecci

Extensively applied in the eighties, although affected by rather large error bars ($\pm$0.25 mag in distance and $\pm$4 Gyr in age), the GC Main Sequence Fitting (MSF) technique derives distances from the comparison of the GC Main Sequence to a suitable "template" formed by metal-poor subdwarfs in the solar neighborhood, whose distances are accurately measured via trigonometric parallaxes. This method has been substantially renewed by the release of the Hipparcos trigonometric parallax catalogue in June 1997.

The Hipparcos based MSF technique has produced a "stretching" of the GC distances which definitely favors the *long astronomical distance scale*, and, in turn, an inferred age scale *younger* by 2-3 Gyrs (Carretta et al. 2000, and references therein).

An ESO large programme, carried out in 2000–2002, has permitted to reduce the residual uncertainty in the MSF distances to about $\pm$0.07 mag (i.e., dominated by the parallax error) and the corresponding errors in the GC ages to $\pm$1 Gyr, by addressing these effects. We have published results (Gratton et al. 2003) for NGC 104, NGC 6397, and NGC 6752. From a strictly homogeneous analysis of cluster main sequence turn-off (MSTO) stars and field subdwarfs with well determined parallax, we have been able to use a homogeneous metallicity and reddenings scale. This has reduced the final error on GC distances to $\pm$0.07, and on ages to $\pm$1.1 Gyr. From these 3 Galactic GCS, the age of the oldest globulars in our Galaxy is 13.7$\pm$0.8$\pm$0.6 Gyr (random and systematic errors; Gratton et al. 2003), fully compatible with the very recent determination of the age of the universe by WMAP. New observing time with FLAMES has been assigned in P73 to extend this study to many other GCs.

This work is in collaboration with Carretta, Gratton (INAF–Padova Obs.), Grundahl (Aarhus Univ., DK).

1.2.3 The companion to the binary MSP in NGC 6397

People involved at OAB: Bragaglia, Possenti

During a large term project dedicated to finding and understanding millisecond pulsars (MSP) in globular clusters, a particularly interesting system was discovered in NGC 6397 and optically identified (Ferraro et al. 2001)

This MSP binary system contains a tidally deformed star. This is the first case of a MSP in a binary system with such an exotic companion and it could represent the first detection of a new-born MSP. The discovery of this system, thanks to the unusual brightness of the companion (V=16.6), allowed us unprecedented detailed spectroscopic observations, opening a new unexplored window to the study of MSPs in clusters. We have performed phase resolved spectroscopy at high resolution (with UVES@VLT) which allowed us to determine the radial velocity curve and many orbital parameters of this binary system (Ferraro et al. 2003). These observations have shown a surprising detection of strong HeI absorption lines, completely unexpected in a low-temperature star as the MSP companion. This feature implies the existence of atmospheric regions at $T > 10,000$ K, significantly warmer that the rest of the star. The intensity of the lines correlates with the orbital phase, suggesting the presence of a small spot onto the companion surface, heated by the millisecond pulsar flux. We have also performed the analysis of the complex structure of the Hα emission line, which has allowed us to map the structure of the gas released by the donor star (Sabbi et al. 2003a).

Finally, abundance analysis has been performed, even with some difficulties due to the high rotational velocity (about 50 km s^{-1}). We have found that elemental abundances are fully compatible with the ones of "normal" stars in NGC 6397, with the exception of Li, Ca, and C. The almost complete absence of C suggests that the star has been heavily peeled, and favours the scenario where the companion is a MSTO star which has lost most of its mass (Sabbi et al. 2003b).

This research is in collaboration with D'Amico (INAF–OA Cagliari), Ferraro and Sabbi (Dip. Astr. BO).

1.2.4 ω Centauri

People involved at OAB: Bellazzini, Origlia, Pancino, Sollima

ω Centauri is the largest ($M = 4 \times 10^6 M_\odot$, Pryor & Meylan 1993), brightest cluster in the Galactic Halo, and it is the *only* GC which shows undisputed variations in the chemical content of its stars. From this point of view, ω Cen could be considered a *bridge* system between genuine globulars, which are unable to retain the gas ejected by their former massive stars, and dwarf galaxies, which are the least massive self-enriching stellar systems known. We are currently carrying out a long-term project, aimed at performing a detailed photometric and spectroscopic study of the stellar population in this cluster.

The first surprising result was the discovery of a distinct, anomalous RGB (RGB-a), significantly redder than the bulk of the normal RGB stars (Pancino et al. 2000). Prompted by this result, we have then carried out a systematic spectroscopic and photometric observational campaign, using the current generation of instruments available at ESO, on board of HST and at other international telescopes. A spectroscopic screening of the multi-populations of red giants in ω Cen has been carried out by means of high-resolution echelle spectra with UVES@VLT (Pancino 2003, PhD thesis) and medium-resolution infrared spectra with SOFI@NTT of more than 40 stars in 2002 (see Origlia et al. 2003 and references therein). During 2003 we have acquired more than 700 high-resolution spectra of ω Cen giants with UVES and FLAMES, within the GTO programmes of the ITAL-FLAMES consortium. The data reduction is in progress. In the meantime the results of a detailed study of the structural properties of ω Cen as a whole and of its sub-populations have been published (Pancino et al. 2003).

The results of new NIR and optical photometric campaigns are in press or in preparation. In this vein the most striking result comes from deep HST-ACS photometry of the central region of the cluster (Ferraro et al. 2004) that clearly evidences for the first time substructures in the CMD at the level of the sub-giant branch (SGB, see Fig. 1). In particular, an anomalous SGB is clearly identified which is significantly fainter than that associated with the bulk of the cluster population. At present it does not seem possible to obtain a satisfying explanation of such a feature in terms of age/metallicity/He-abundance variations. We are reducing low-resolution spectra of stars

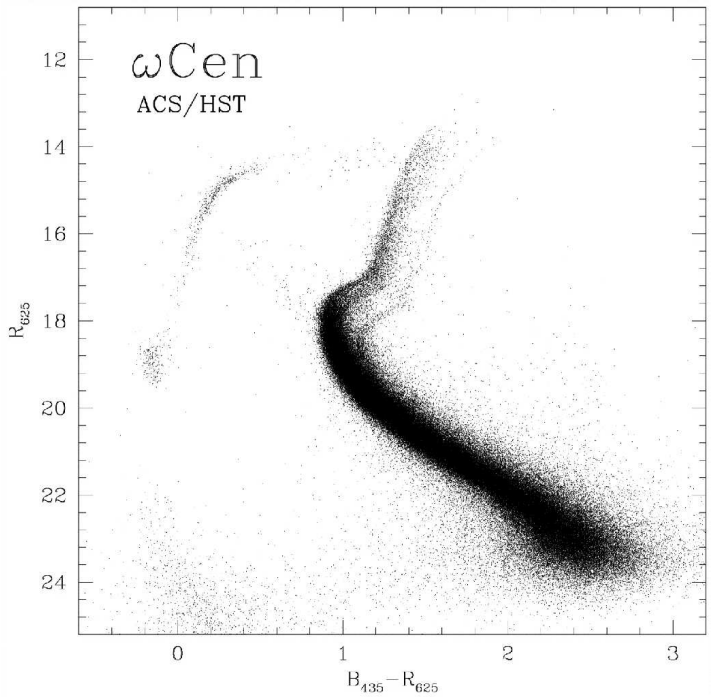


Figure 1: (R625, B435-R625) CMD for more than 400,000 stars identified in the nine ACS fields. The anomalous SGB is clearly visible, along with the complex substructures of the TO-SGB region of ω Cen.

in the anomalous SGB to clarify their nature. Preliminary results indicate that such stars are indeed members of the cluster and that they are quite metal-rich ($[Fe/H] \sim -0.6$).

The Bologna key project on ω Cen is fully active, with a wealth of data being reduced, several observational proposals already accepted, one PhD student (A. Sollima) and one post-doc (E. Pancino) working full-time on this topic. The work is carried out in collaboration with F. Ferraro (Astr. Dept., Univ. of Bologna).

1.2.5 Abundances in Globular Clusters

Halo Globular Clusters

Stars in each GC, with the exception of ω Cen and possibly of M 22, generally have a very homogeneous composition as far as Iron-peak and α-elements are considered, while abundances of lighter elements

(from C to Al) show a complex, not yet fully explained, pattern (i.e., CN-CH band strength anti-correlation, Na-O anti-correlation, etc.) not seen in field stars. Proposed explanations have varied from an *in situ* mechanism (e.g., very deep mixing of nuclear-processed material) to an external source of material (either primordial proto-cluster gas or processed material from a polluting companion). Both explanations could work for RGB stars, while main sequence stars require the latter.

Abundances along the RGB

People involved at OAB: Bragaglia, Bellazzini, Cacciari, Monaco, Pancino.

In the framework of a large programme in collaboration with researchers in Padova and Roma, we aim at deriving accurate abundances for a representative number of giants in several globular clusters by using the multiplex FLAMES facility at the VLT (UVES + GIRAFFE). Our first target has been M 22, since there are reasons to believe that M 22 could have a significant dispersion in metallicity. Even though the effect is going to be smaller than in ω Cen, the detection of such a spread in metallicity would indicate that at least another globular cluster in our Galaxy has experienced the same kind of chemical enrichment history as ω Cen. Such a discovery would be of invaluable help in understanding the mechanism of formation of ω Cen and would shed light on the processes that are at the basis of the halo formation and evolution. Accurate wide field photometry of M22 has already been published (Monaco et al. 2004), showing that the metallicity spread should be $\leq$ 0.1 dex. Using this catalog, we have selected $\sim$ 250 stars that have been observed with UVES and FLAMES and the data analysis is under way.

Another project on the RGB of a quite peculiar GC (NGC 2808) has been conducted, based on Science Verification observations for FLAMES@VLT, proposed by Cacciari and Bragaglia. A sample of 137 RGB stars (the largest ever in a given cluster) have been observed with UVES/FLAMES and GIRAFFE, monitoring about 3 mag from the RGB tip, and taking spectra in regions containing mass loss and chromospheric activity diagnostics: Ca II H+K, Na I D, and Hα lines (see Fig. 2). We have found indication of outward mass motions, and confirmed the presence of chromospheres (Cacciari et al. 2004).

The same dataset has been used to study the Na abundance along the RGB. From 82 stars we determined a large star-to-star scatter

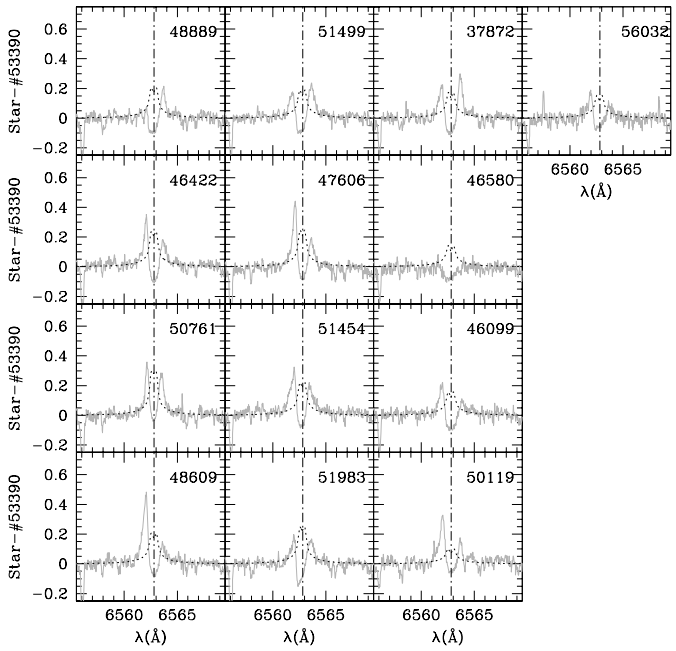


Figure 2: Region centered on Hα of 13 stars on the RGB in NGC 2808 observed with UVES. From all spectra we have subtracted a template profile (star 53390, which did not show any evidence of irregularities) to enhance asymmetries; results are plotted as solid gray lines. The dotted lines show instead the differences with the corresponding theoretical profiles.

in Na, at all magnitude levels. Comparison with other clusters has led us to suggest a primordial origin for the different Na abundances (Carretta et al. 2003).

Similar work has recently begun on science commissioning data obtained on 47 Tuc.

Abundances of Main Sequence Turn-Off stars
People involved at OAB: Bragaglia, Clementini

Only recently stars near the MSTO have become observable at the necessary S/N and resolution. As part of an ESO Large Programme (PI Gratton), we have acquired with UVES@VLT in 2000, 2001 and 2002 (30 nights in total) high resolution spectra (R$\geq$ 40000) of a large

number of stars at the MSTO and at the base of the sub-giant branch in NGC 6752, NGC 6397, 47 Tuc, NGC 6809 and NGC 7099. Abundance analysis for Fe, Li, and other elements has been completed for the first three clusters (e.g., Gratton et al. 2001, Bonifacio et al. 2002, James et al. 2004, Carretta et al. 2004).

The [Fe/H] abundances determined for NGC 6752, NGC 6397 and 47 Tuc (identical for MSTO and subgiant stars; Gratton et al. 2001, 2003) have removed one of the possible major sources of uncertainty claimed to affect the MSF distances (see Section 1.2.2). Our analysis has also put a strong constraint on sedimentation.

Furthermore, we have found presence of O-Na and Mg-Al anticorrelations in MSTO stars in NGC 6752 (Gratton et al. 2001) and 47 Tuc (Carretta et al. 2004), hence ruling out internal mixing as the cause of such anomalies.

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

The galactic bulge: globular clusters and field populations
People involved at OAB: Origlia, Valenti.

Bulge GCs are a fundamental stellar population of our Galaxy and it is most interesting to compare their detailed compositions with the Galactic bulge field population (McWilliam & Rich 1994). For many of these bulge clusters, foreground extinction is so large as to preclude any photometric and spectroscopic optical study. In the last few years we have undertaken a long-term project devoted to study a representative sample of Bulge globular clusters in the infrared.

Using the SOFI medium-resolution imager/spectrograph at the ESO NTT telescope and the NIRSPEC high-resolution echelle spectrograph at Keck II, we are performing a systematic survey to measure spectra of several tens of M-giant stars in bulge globular clusters, in Baade's window and near the galactic center. The spectral analysis is in progress.

We measure several single roto-vibrational OH lines and CO bandheads to derive accurate Oxygen and Carbon abundances. Other metal abundances can be derived from the atomic lines of Fe I, Mg I, Si I, Ti I, Ca I and Al I. Abundance analysis is performed by using full spectral synthesis techniques and equivalent width measurements of representative lines.

We find an overall [α/Fe] enhancement up to about solar metallicities, both in the cluster and field populations, that is consistent with a scenario in which the bulge formed early, with rapid enrichment (Origlia, Rich & Castro 2002, Origlia & Rich 2004).

This reasearch is in collaboration with F. Ferraro (Astron. Dept., Bologna University) and R.M. Rich (UCLA, USA).

1.2.6 The Globular Cluster System of the Andromeda galaxy

People involved at OAB: Bellazzini, Buzzoni, Cacciari, Federici, Fusi Pecci, Parmeggiani, Galleti.

The M31 globular cluster system is the largest found in the Local Group, sufficiently close to allow detailed observations, and little affected by reddening, at least for a large outer sub-set. Since the intrinsic depth of the spheroid is small compared to the distance to M31, in the study of the basic properties and comparisons one can remove the degeneracies introduced by the uncertain knowledge of the individual distances.

M31 offers the unique opportunity of studying the GC system of a spiral galaxy that is similar to the Milky Way in very good detail and without some of the limitations that affect the Galactic GC system. The OAB M31 team, in collaboration with 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 use 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.

In this framework, we have revised the catalog of candidate GCs of M31 (Galleti et al. 2004), providing a comprehensive list of 1164 candidates – the *revised Bologna catalogue* – with full and updated photometric information, including also JHK photometry for 693 of them that has become recently available from the 2MASS database. The final *revised Bologna catalog* includes 337 confirmed GCs, 688 GC candidates, 10 objects with controversial classification, 70 confirmed galaxies, 55 confirmed stars and 4 HII regions lying within ~ 3 deg from the center of M31. It is the most comprehensive list presently available of confirmed and candidate M31 globular clusters, and is available in electronic form at the CDS (Strasbourg Data Center).

Using this newly assembled database we have found that the $V-K$ color provides a powerful tool to discriminate between M31 clusters and background galaxies, and we have identified a subset of 83 blue GC candidates that have a high probability of being true M31 clusters and that will be observed spectroscopically to ascertain their nature. The confirmed clusters will be important additional kinematical probes for a better determination of the mass profile and the total mass of M31.

A large sample of confirmed GCs in M31 has been observed with HST with the aim of comparing the characteristics of these stellar populations with those of the Milky Way, and to measure the dependence of the HB luminosity on metallicity for a sample of clusters at the same distance. The CMDs obtained from WFPC2/HST observations for a total sample of 19 GCs in M31 [in collaboration with Rich (UCLA)] reach at least one magnitude fainter than the Horizontal Branch level. Our analysis shows that M31 globular clusters are very similar to the Milky Way globular clusters, and that there is no strong indication of an intemediate age cluster population analogous to those found (for example) in the SMC.

1.2.7 Globular Cluster Systems in external galaxies

People involved at OAB: Cacciari, Federici, Galleti

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

In this framework, we have obtained deep MOS spectroscopy using FORS1 at the VLT of about 75 globular clusters candidates in the Sombrero galaxy (NGC4594), an early-type spiral with a dominant bulge.

Wide field imaging (BVR) of NGC 4594 was taken with the ESO/MPG 2.2m telescope. The sample of highly probable globular cluster candidates selected using color and shape criteria shows a bimodal color distribution and has been observed with VIMOS in April 2003 during Period 71. Fifty-seven candidates out to ~ 40 kpc in the halo of the galaxy were confirmed to be bona-fide globular clusters, 27 of which

are new. The metallicities, derived from absorption line indices, confirm a bimodal [Fe/H] distribution, in agreement with the results of the photometry (Moretti et al. 2003). The distribution was fitted with two gaussians peaking at $[Fe/H] \approx -1.7$ and $[Fe/H] \approx -0.7$, very similar to those of globular clusters in our Galaxy. Preliminary results have been presented by Held et al. (2003).

Since efficient spectroscopic observations require a previous identification of a sample of bona-fide globular cluster candidates, and in preparation for a systematic spectroscopic study at the VLT with FLAMES or VIMOS, we have undertaken a wide-field multicolor imaging survey of galaxies of different morphological types (E/S0) as far as the Virgo cluster: NGC 3115, NGC 4526, NGC 4406, NGC 253, NGC 5128, NGC 4594. For one of these galaxies, NGC 253, we have already analysed our 2.2m-WFI BVI images (FoV $= 33 \times 34$ arcmin) and identified about 400 globular cluster candidates (Galleti et al. 2004). This number of candidates is much larger than the numbers found in all previous surveys of this galaxy, and even taking into account a significant degree of contamination it represents a major improvement over all previous studies.
This research is in collaboration with Held, Moretti, Rizzi (INAF - Padova Obs.) and Testa (INAF - Rome Obs.)

1.3 Nearby Galaxies

1.3.1 The stellar cluster system of the Magellanic Clouds

People involved at OAB: Origlia, Fusi Pecci

The spectral evolution of a Simple Stellar Population (SSP) and its most evident color glitches are ideal *clocks* for dating primeval galaxies and deriving a suitable, empirical relation between lookback time and redshift.

The empirical calibration of the clock which settles the spectral evolution of SSPs and its readability are the primary goals of our project. The globular cluster system of the Magellanic Clouds (MC) provides a unique opportunity to investigate the integrated spectrophotometric behavior of stellar populations as a function of both age and chemical composition. We are tackling these major astrophysical objectives by means of a coordinated spectrophotometric survey on a representative sample of MC clusters, aimed at determining with great

accuracy and in a homogeneous way their age, metallicity and overall integrated spectral properties.

During a number of successful observing runs with SOFI@NTT, our group secured high quality J, H, K photometry of 20 LMC clusters spanning the age range between 50 Myr and a few Gyr. Popolous and complete near-IR CMDs covering the entire RGB extension have been obtained. The high quality and homogeneity of such an IR database will provide the most accurate empirical determination of the occurrence of the so-called AGB and RGB phase transitions and their contribution to the cluster integrated light in each photometric IR band-pass and in bolometric. These empirical estimates compared to those of the models will allow to calibrate the integrated magnitude and colour glitches in terms of age, i.e., to reliably calibrate the stellar clock which is the fundamental engine of any evolutionary synthesis technique. The results based on the first set of data have been recently published (see Ferraro et al. 2004) and demonstrated that the full development of the RGB occurs at ages around 700 Myr and is a relatively fast event (duration ~ 300 Myr).

The correct reading of the age from a SSP requires the accurate knowledge of the global metallicity. This major piece of information is still lacking, namely a self-consistent metallicity scale and a detailed description of the abundance patterns of MC clusters. In order to fill such a gap, we are performing a spectroscopic survey at medium-high resolution in the visual (by using UVES+GIRAFFE at the ESO-VLT) and in the IR (by using SOFI@NTT) for a representative sample of MC clusters. Such high quality spectroscopic data coupled with the photometric database secured by our group over the last 10 years will allow to calibrate the evolutionary clock, a fundamental tool to trace the history of star formation and evolution of primordial galaxies.

This research is in collaboration with F. Ferraro (Bologna University), V. Testa (INAF–Rome Obs.), C. Maraston (Max-Planck Munich, Germany).

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

People involved at OAB: Bellazzini, Monaco, Pancino.

There is now a growing body of observational evidence in favour of an inhomogeneous halo, where the tracks of the slow building up by

hierarchical merging of sub-units should be still observable. The Sagittarius dwarf Spheroidal Galaxy (Sgr dSph; Ibata et al. 1994) is the most evident and striking example of a *real time* accretion event occurring in the Galactic Halo. The main body of Sgr dSph orbits well within the Galactic spheroid ($R_{GC} \simeq 16$ kpc) and shows clear signs of being accreted and disrupted by the Galactic tidal field. Thus, the Sgr dSph is (and has been) one of the major contributors to the stellar content of the whole Galactic Halo.

In this framework, we have started a large photometric survey of this disrupting dSph. At present we have assembled a catalogue comprising V, I photometry and accurate astrometry (to within ± 0.2 arcsec) for $\sim 500,000$ individual stars in a $1 \times 1\,\mathrm{deg}^2$ area centered on the globular cluster M54, which coincides with the main density peak of the Sgr galaxy. Near-Infrared J, H, K magnitudes for many thousands of stars have also been obtained from the Point Source catalogue of the 2MASS survey. This large database provided the basis for a detailed study of the chemical composition of Sgr stars to be performed with FLAMES@VLT, within the GTO program of the ITAL-FLAMES consortium.

Meanwhile, the analysis of the photometric database (Monaco et al. 2002) is ongoing. We have detected blue horizontal branch stars unequivocally associated with the Sgr galaxy, thus demonstrating that the system contains also old and metal-poor stars (Monaco et al. 2003). We have also shown that there is a nucleus at the center of Sgr, coincident in position with the globular cluster M54 but populated by stars that cannot belong to the cluster (much more metal-rich; Monaco et al. 2004). This finding shows that Sgr was indeed a nucleated galaxy, independently of the presence of M54.

It is now established that the disruption of the Sgr dSph left a track of stars (torn away from the original Sgr dSph) that forms a long-lived structure, following the past orbital path of the galaxy, i.e. the Sgr Stream (Ibata et al. 2001). We have started a program to search for possible relations between known globular clusters and the Sgr Stream. As a first important result we have found that the orbit of the Sgr galaxy is a preferential locus in the phase-space for the globular clusters in the range $10 \leq R_{GC} \leq 40$ kpc (Bellazzini, Ferraro & Ibata 2003). We have demonstrated that the observed phase-space clustering is statistically significant, thus indicating that Sgr has left behind in the Galactic halo not only a stream of stars but also some globular clusters. A first pilot search of Sgr Stream stars around can-

didate Stream clusters brought to the observational confirmation of two clusters as bona-fide members of the Sgr stream, i.e. Pal 12 and NGC 4147.

This research is in collaboration with Ferraro (Astron. Dept., University of Bologna), and with the INAF–Trieste Observatory group (Bonifacio, Molaro, Zaggia) within the ITAL-FLAMES Consortium. The research on the Sagittarius Stream is carried out in collaboration with R. Ibata (Observatoire de Strasbourg).

1.3.3 The accreted component of the Galactic disc: the Canis Major dwarf spheroidal

People involved at OAB: Bellazzini, Monaco.

The accretion of the Sagittarius galaxy is currently the only strong evidence that the Milky Way is absorbing satellite galaxies. However, the ring-like structure that has recently been discovered around the galaxy could be the consequence of another such event. First discovered as an overdensity of blue stars in the Sloan Digital Sky Survey (Newberg et al. 2002), the "ring" has since been probed using the INT WFS photometry (Ibata et al. 2003), the SDSS spectrometry and photometry (Yanni et al. 2003) and the 2MASS M giants (Rocha-Pinto et al. 2003). Surrounding the Galactic disk, its galactocentric distance ranges from ~ 15 kpc to ~ 20 kpc in fields taken within 30 deg of the Galactic plane and for $227\,\mathrm{deg} > l > 122\,\mathrm{deg}$. It has been proposed (Ibata et al. 2003; Yanni et al. 2003; Helmi et al. 2003) that the structure could be the stellar stream stripped away by the Milky Way tides from a satellite galaxy whose orbital plane is close to the plane of the galaxy.

While studying the large scale structure of the ring using M giant stars from the 2MASS database, we have discovered a large overdensity of stars in the southern Galactic hemisphere (Martin et al. 2003; hereafter M04), in the direction of the Canis Major constellation, approximately enclosed between $l = 220^o$ and $l = 260^o$ and $-20^o \leq b \leq 0^o$ (see Fig. 3). The elliptical shape of this overdensity, its overall structure and its spatial coincidence with a small compact group of globular clusters (Bellazzini et al. 2003c) strongly suggest that we have discovered a previously unknown dwarf galaxy, whose progressive disruption by the Galactic tidal field is probably at the origin of the ring (see also Frinchaboy et al. 2004). The newly discov-

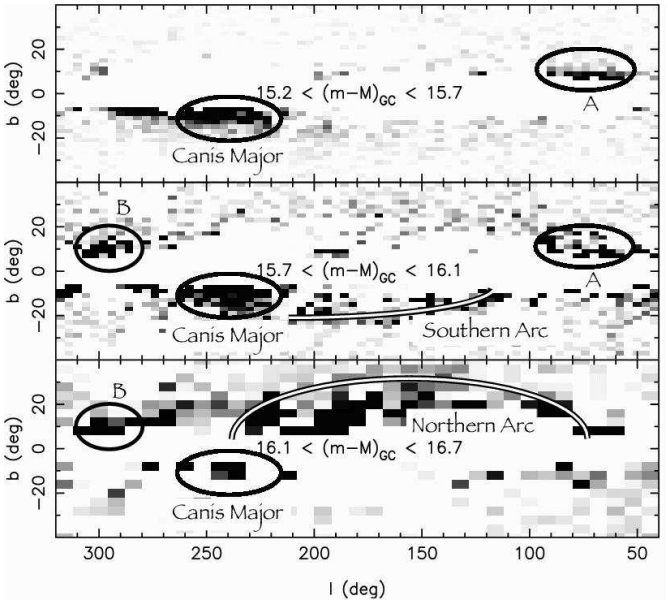


Figure 3: Pixel maps of the distribution of the differences in M-giant starcounts between the two Galactic hemispheres, for different ranges of Galactocentric distance modulus. Note the large elliptical overdensity in the southern hemisphere at $220^o < l < 260^o$, particularly evident in the middle panel. The northern part of the Ring is also visible toward the Galactic Anticenter.

ered stellar systems turned out to be the nearest of all the Milky Way satellites, lying at 8-10 kpc (i.e., 26000–32600 light years).

We searched the literature for wide field photometry of open clusters located in the foreground of the Canis Major object (Bellazzini et al. 2003, hereafter B03) and we detected its main sequence (MS) stars in several directions within the above quoted range. In particular, from the ESO-WFI photometry of the cluster NGC 2477 by Momany et al. (2001), we obtained the first optical CMD of the system, fully confirming the results of M04. Finally, we have found very recent WFI observations of a field located at $(l, b) = (244.2^o; -8.2^o)$, just ~ 5 degrees from the center of the newly discovered structure. The data further confirm our discovery of a previously unknown stellar system, *the Canis Major galaxy (CMa)*, a new nearby dwarf satellite of the Milky Way.

The reduction of the data of a large spectroscopic campaign per-

formed at the 2dF-AAT is currently in progress. Preliminary results suggest that the Canis Major system has a distinct velocity with respect to ordinary disc stars and has a velocity dispersion typical of local dwarf spheroidals ($\sigma \sim 10$ km s^{-1}).

The "in-plane" orbit of the newly discovered relic strongly suggests that we are witnessing – for the first time – a phenomenon related to the last phases of the hierarchical assembly of the thick disc. The discovery had a large echo on the scientific press worldwide.[1]
This research is in collaboration with: R. Ibata, N. Martin (Obs. Strasbourg), G. Lewis (Sidney University), M.J. Irwin (Cambridge - UK).

1.3.4 Dwarf spheroidal galaxies

People involved at OAB: Bellazzini, Origlia, Pancino

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

Our programme, aimed at the revision of the distance scale of the Local Group, based on our new RGB tip calibration (Bellazzini, Ferraro & Pancino 2001), is proceeding. We obtained deep photometry for a number of dwarf galaxies and the results of a comparative study of the Ursa Minor and Draco dSph has been completed. The most interesting result is the detection of a striking difference in the structure in these otherwise similar galaxies. In particular, UMi shows up significant sub-structures that may be interpreted as a signature of strong tidal stress.

Our photometric survey of the evolved population of local dwarf galaxies led to the discovery of the RGB bump in a number of dSph galaxies (Sgr, Sex, UMi, Leo II). Such discoveries have opened a new line of research aimed at the interpretation of this observational feature in composite stellar populations, in order to obtain information

[1] See http://www.bo.astro.it/cma/webpage_e.html for an incomplete list of press reports.

on the early star formation histories of these galaxies from this new observational constraint (see Bellazzini 2003).

This research is in collaboration with Ferraro and Sabbi (Astron. Dept., University of Bologna), and Oliva (INAF–Arcetri/TNG Obs.).

1.3.5 Star formation histories in late-type dwarf galaxies

People involved at OAB: Origlia, Romano, Tosi.

Late-type dwarf galaxies are playing an increasingly central role in understanding galaxy evolution, because their proximity allows one to examine in detail important issues, such as the occurrence of galactic winds, the chemical enrichment of the interstellar and intergalactic media, the photometric evolution of galaxies. Besides, their low level of evolution, as implied by the low metallicity and the high gas content, makes these systems the most similar to primeval galaxies and, therefore, the most useful to infer the primordial galaxy conditions. Furthermore, they have been suggested to represent the building blocks of larger galaxies. Understanding how late-type dwarfs evolve and what were their conditions at early epochs is then crucial also for cosmological purposes. It is thus fundamental to derive the star formation history (SFH) in a number of representative systems of the major morphological sub-classes: blue compact galaxies, dwarf irregulars, giant irregulars (Tosi 2003a,b).

To this aim we are undertaking a long term project in collaboration with Angeretti (Astron. Dept., University of Bologna), Greggio (INAF–Padova Obs.), Annibali (Sissa), Monelli (Univ. Tor Vergata), Aloisi, Clampin, Leitherer and Nota (Baltimore, USA), and Tolstoy (Groningen, NL) to study, from deep and accurate photometric data (VLT and HST), the stellar populations of a number of dwarfs known to show evidence of galactic winds. So far we have studied IZw18, NGC 1569 and NGC 1705 and observed SBS1415+437 (with ACS@HST) and DDO210 (with FORS@VLT). Time has been allocated at the ACS@HST to study some young clusters in the SMC. The resolved stars allow us to derive the intensity as a function of time of the star formation activity and the IMF of these galaxies back to fairly old epochs with the method of synthetic CMDs pioneered by our group and amply tested and applied by the international community.

In 2003 we have published (Annibali et al. 2003) the study of the SFH in NGC1705 from WFPC2@HST and Nicmos@HST VIJH data

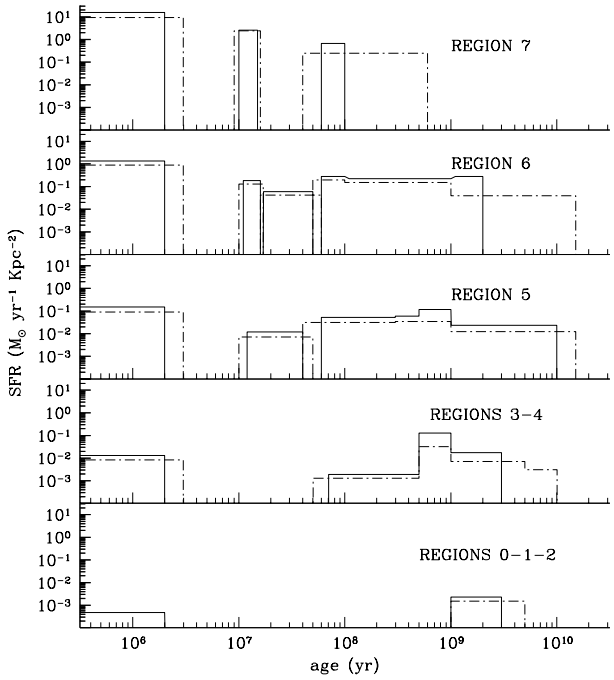


Figure 4: Star formation history of concentric regions of the BCD galaxy NGC1705 as derived from the application of the synthetic CMD method to WFPC2@HST data. Region numbers decrease for increasing distance from the galactic center. Different line types indicate the range of uncertainty. From Annibali et al. (2003).

(see Fig. 4). These data have allowed us to derive the galaxy distance with great accuracy from the red giant branch tip, and to show that this blue compact galaxy has a large fraction of old stars (hence has been strongly active also in remote epochs) and has a population age gradient, with decreasing age for decreasing galactocentric distance. We have applied the synthetic CMD method to concentric regions from the galaxy center to study their SFHs and found that the SF has been fairly continuous everywhere, but with significant ups and downs in the rate and with clear short quiescent intervals. Our study has made us discover that NGC1705 is experiencing now a new strong SF activity. We have completed the study of the U and B WFPC2@HST images of NGC1705 confirming the evolutionary scenario mentioned above and

providing the catalogue of its candidate star clusters (Monelli et al. in preparation).

The synthetic CMD method has been applied also to the Nicmos@HST data on NGC1569 (Angeretti et al. in preparation). This has allowed us to derive the SFH at epochs older than those covered by optical data. We have found that this galaxy has been extremely active also in the past.

We have reduced the VLT data on the Local Group dwarf DDO210; we are now applying extensive artificial star tests to these images to derive the photometric properties (errors, incompleteness, blending) to be inserted in the synthetic CMD code to derive its SF history.

New numerical chemical evolution models have been computed (Recchi et al. 2004) for the blue compact galaxy IZw18, based on the SFHs derived by us (Aloisi et al. 1999) applying the synthetic CMD method to HST data. These new generation models take into account the effects of the supernova explosions on the hydrodynamics of their interstellar medium and the possible onset of galactic winds. Meanwhile, classical chemical evolution models are being computed for IZw18, NGC1569, NGC1705, also assuming the SF history and IMF derived with the synthetic CMD method. These simpler models, once compared with the observed abundances and masses of the examined galaxies, provide useful information on the various parameters and can provide indications on how the yet unknown part of the gas dynamics could behave.

1.4 Synthetic model atmospheres of stars and high-resolution stellar population synthesis

People involved at OAB: Buzzoni

A long-term project has been further carried out in 2003, concerning the computation of a high-resolution synthetic spectral library of stars. The work is in progress with the collaboration of the Mexican colleagues of the Instituto Nacional de Astronomia, Optica y Electronica (INAOE) of Puebla (M. Chavez and E. Bertone), and is part of the PhD thesis of L. Rodriguez, at the INAOE.

The synthetic SEDs rely on the Kurucz (1993) set of model atmospheres, computed by means of the ATLAS9/SYNTHE code (Kurucz

1995), with the "overshooting" update according to the Castelli, Gratton and Kurucz (1997) prescriptions.

In its current version, the theoretical grid of stellar spectra covers the wavelength interval from 912 to 7000 Å (Bertone et al. 2003; Rodriguez-Merino et al. 2003). The library is divided into two sets of spectra computed independently. Part I is in the Far UV–Blue spectral region from 912 to 4500 Å at inverse spectral resolution R = 50,000, while Part II covers the range 3500–7000 Å at R = 500,000. The model grid spans metallicity from [M/H] = −2.0 to +0.5, and considers both dwarf and (super)-giant stars ($\log g$ up to 5.0 dex). The temperature range goes from 4,000 K to 50,000 K. Our library is currently the most extended one available in the literature at such high resolution, and is especially useful for population synthesis studies in order to address key questions on the overall evolutionary properties of stellar systems.

A degraded version of the full SED library (at a 2Å FWHM resolution), more suitable for fitting galaxy and other massive stellar aggregates through population synthesis models, has been produced, and implemented in the Buzzoni (1989, 1995) original code to explore SSP models.

1.5 Pulsating variable stars

Pulsating variable stars are fundamental tools to set the astronomical distance scale, and to sample different stellar populations in galaxies, through the study of the luminosity and luminosity-metallicity relation of the RR Lyrae stars; the Period-Luminosity (PL) and Period-Luminosity-Color (PLC) relations of Anomalous, Type II, and Dwarf Cepheids; the period distribution of the RR Lyrae variables, and the double-mode pulsators.

Population II variable stars and their role in establishing the astronomical distance scale have been a major field of study at the OAB since 1984 (e.g. Cacciari et al. 1987). A number of new projects have been started in more recent years (e.g. "The VSNG project", Clementini 2003), in collaboration with researchers of the INAF–Padova, Napoli and Merate Observatories, to map out the variable star content in a number of Local Group galaxies of different morphological type.

RR Lyrae stars are excellent tracers of the oldest stellar population in galaxies (and therefore of the epoch of galaxy formation) and

are the primary Population II distance indicators in the LG. Their absolute visual magnitude M_V(RR) sets the luminosity of the horizontal branch (HB) and its dependence on metal abundance, usually described as a linear relation: $M_V(RR) = \alpha \times [Fe/H] + \beta$. The zeropoint of this relation constrains the GGC distances and absolute ages through the TO luminosity calibration, providing in turn a lower limit to the cosmic age. The slope gives clues on the GGC relative ages and on the time scale of Galactic halo formation and early evolution. There is now a growing consensus on a zero point $\beta \sim 0.6$ at [Fe/H] $= -1.5$ (Cacciari & Clementini 2003) which supports the *long astronomical distance scale* (see Clementini et al. 2003a). However, the slope α and its uniqueness are still a matter of debate, with literature values in the range from 0.30 mag/dex to 0.18–0.20 mag/dex (Cacciari 1999, Carretta et al. 2000) and empirical (Rey et al. 2000) and theoretical (Caputo et al. 2000) evidence for a non-linearity of the M_V(RR)-[Fe/H] relation for GGCs.

The value of β from the Baade-Wesselink method
People involved at OAB: Cacciari, Clementini.

The zeropoint of the luminosity-metallicity relation of the Galactic RR Lyrae stars is investigated using the Baade-Wesselink (BW) method on two RR Lyrae variables in the globular cluster M3. We are testing the effects on the 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). We have reduced the high resolution spectra obtained with SARG@TNG and built up accurate radial velocity curves. Reduction of the IR (K-band) photometry obtained with ARNICA@TNG is in progress.

The value of α from metal abundances of RR Lyrae stars in the LMC and in Sculptor

People involved at OAB: Bragaglia, Clementini, Maio.

The slope of the luminosity-metallicity relation followed by RR Lyrae stars can be directly measured using a population of RR Lyrae variables all at the same distance, and spanning a suitable range in metal abundance. RR Lyrae stars in external galaxies play a key role in this respect, since they can be considered at the same distance from us, are numerous, and generally span large metallicity ranges. The slope of the luminosity-metallicity relation for RR Lyrae stars in the Large Magellanic Cloud (LMC) bar has been investigated in collaboration with Carretta, Gratton (INAF–Padova Obs.) and Di Fabrizio (INAF–TNG), using low resolution spectroscopy obtained with FORS1@VLT.

These spectroscopic data have allowed us to measure metallicities accurate to $\sim$ 0.15-0.20 dex using a revised version of the ΔS index (Preston 1959; Gratton et al. 2004) for a sample of about 100 RR Lyrae variables in the bar of the LMC. The derived metal abundances range from -0.27 to -2.12 with an average value of [Fe/H] = $-1.48 \pm 0.03 \pm 0.06$. Individual metallicities were combined with the high quality photometric data by Clementini et al. (2003a) to determine the slope of the luminosity-metallicity relation of the LMC field RR Lyrae stars: $\Delta \mathrm{M}_V(\mathrm{RR})/[\mathrm{Fe/H}] = 0.214 \pm 0.047$ mag/dex. This mild slope is in very good agreement with the one obtained by recent results on the HB luminosity of GCs in M31, and with results from the BW analysis of MW field RR Lyrae stars (Fernley et al. 1998), implying that the same luminosity-metallicity relation for HB stars is valid in these three different environments, and that a significant age-metallicity dependence is likely to exist in the family of the GGCs.

New observing time (10 hours FORS2@VLT service mode) obtained in 2003 has been devoted to multi-slit spectroscopy of about 150 RR Lyrae stars in the dwarf spheroidal galaxy Sculptor. The spectroscopic data have been fully reduced and their analysis is in progress. The derived metalicities will allow us to establish the luminosity-metallicity relation followed by the RR Lyrae in Sculptor. The comparison with our results for the LMC will then provide a clearcut proof on whether the slope of the luminosity-metallicity relation for RR Lyrae stars is universal, with fundamental bearings upon the entire Population II distance scale. This study is in collaboration with Gratton, Held (INAF–Padova Obs.), Ripepi (INAF–Napoli Obs.).

1.5.1 Distance to the Large Magellanic Cloud

People involved at OAB: Bragaglia, Clementini, Maio.

The luminosities of RR Lyrae and clump stars in the bar of the LMC and their role in measuring distances have been investigated in collaboration with Carretta, Gratton (INAF–Padova Obs.) and Di Fabrizio (INAF–TNG).

B, V, I light curves have been obtained for 129 RR Lyrae stars, 4 candidate Anomalous Cepheids, 11 Classical Cepheids, 11 eclipsing binaries, and one δ Scuti star in two fields located close to the bar of the LMC. The complete catalogue of the individual photometric measurements and light curves is provided in Di Fabrizio et al. (2004). A very accurate estimate of the average apparent luminosity of the LMC RR Lyrae and clump stars and independent estimate of the local LMC reddening have been obtained from these photometric data. The dereddened apparent average luminosity of the LMC RR Lyrae stars defined by our study has been combined with a number of independent determinations of the absolute luminosity of RR Lyrae stars, to obtain estimates of the distance to the LMC. The derived values are only 1 σ shorter than provided by the Population I distance indicators and make it possible to reconcile the *short-* and *long-distance scales* on a common value for the distance modulus of the LMC of $\mu_{\rm LMC} = 18.515 \pm 0.085$ mag (Clementini et al. 2003a).

In collaboration with M. Marconi (INAF–Napoli Obs.) the extensive and detailed grid of nonlinear convective pulsation models of RR Lyrae stars computed by Bono et al. (2001) and Marconi et al. (2004) has been used to reproduce the observed V, B light curves of 7 *ab*- and 7 *c*-type pulsators in our LMC RR Lyrae sample. The method performs the theoretical reproduction of both the general features and detailed morphology of the observed light curves and provides in turn an independent estimate of the distance to the LMC that is fully consistent with the *long distance scale* (Marconi & Clementini 2004, in preparation).

In collaboration with McNamara (Brigham Young Univ.) we have used the improved version of the period-luminosity relation for δ Scuti stars defined by McNamara (2003) to derive an independent estimate of the distance to the LMC based on the δ Scuti star identified in one of our LMC fields (Clementini & McNamara 2004, in preparation).

1.5.2 Variable stars in Local Group galaxies

People involved at OAB: Baldacci, Clementini, Maio.

Increasing samples of short period pulsating variable stars populating the classical instability strip from the horizontal branch of the oldest population to a few magnitudes brighter are being found in several LG galaxies, irrespective of the galaxy morphological type (Baldacci et al. 2004). The detection and study of the short period pulsating variables in a number of Local Group Galaxies (Leo I, NGC 6822, Fornax, Ursa Minor) is being carried out in collaboration with Held, Saviane, Momany and Rizzi (INAF–Padova Obs.), Poretti (INAF–Brera Obs.), Marconi, Musella, Ripepi (INAF–Napoli Obs.), Di Fabrizio (INAF–TNG), Smith (MSU), Catelan (PUC, Chile), Pritzl (Macalester Univ.).

Fundamental assets of our study are: (i) the collection of photometric data with wide field imagers and large aperture telescopes (e.g. the Wide Field Imagers of the ESO/MPI 2.2m and of the CTIO/BLANCO 4m telescopes; the ESO Very Large Telescopes and the Magellan 6.5m telescope); (ii) the use of most reliable PSF-fitting packages for the photometric reductions (DAOPHOT and ALLFRAME, Stetson 1994, 1996); (iii) the adoption of state-of-the-art techniques for the detection of variable stars in crowded fields (the Optimal Image Subtraction Method and the package ISIS2.1; Alard 2000); and the development of tools specifically designed for the study of single and double-mode pulsators (Graphycal Analyzer of TIme Series, Clementini et al. 2000) and for variable star data archive. See Clementini (2003) and Clementini et al. (2004a) for a general description of the project.

Based on multicolour WFI@2.2m time series photometry about 250 variable stars have been detected in the Leo I dwarf spheroidal galaxy. RR Lyrae stars represent about 4/5 of the sample. They provide unambiguous evidence for the presence of old metal-poor stars all the way to the innermost regions of this galaxy. The remaining 1/5 variables are Anomalous Cepheids. They trace the intermediate age ($t \sim 5$ Gyr) stellar component and appear to be more centrally concentrated (Baldacci et al. 2003).

The same type of study conducted on the dwarf irregular galaxy NGC6822 using FORS1@VLT led to the discovery of about 450 candidate variable stars (Baldacci et al. 2003, 2004). We obtained the

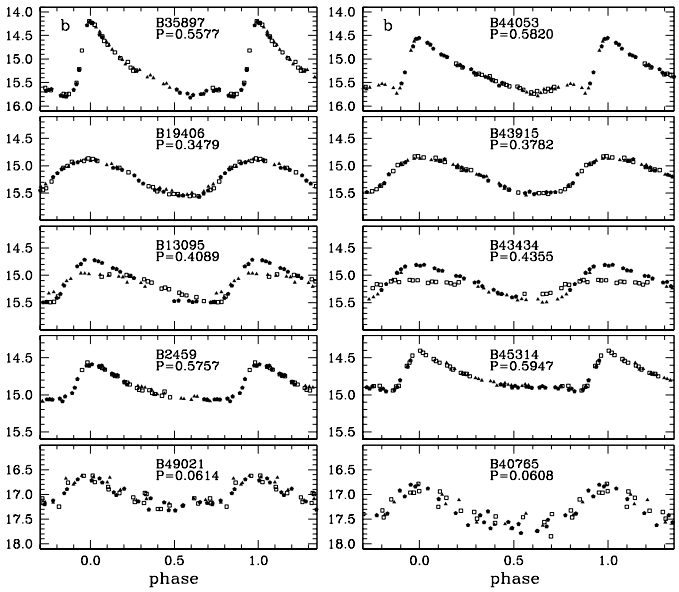


Figure 5: Instrumental b light curves for variable stars in the field of the Fornax dwarf spheroidal galaxy (left panel) and in the galaxy globular cluster For 3 (right panel) from WFI observations. From top to bottom: ab-, c-, and d-type RR Lyrae ($< V >\sim 21.3$ mag), Anomalous Cepheids ($< V >\sim 20$ mag), and Dwarf Cepheids ($< V >\sim 23$ mag).

first identification of RR Lyrae stars tracing the old stellar component in NGC 6822, and leading to the distance modulus: $(m-M)_0 = 23.36 \pm 0.17$. We also found a significant population of small-amplitude, short-period variable stars filling the instability strip starting at luminosities only a few tenths of a magnitude brighter than the RR Lyrae stars. Given the extended star-formation history of NGC 6822, these variables are likely to originate from a population of intermediate-age, metal-poor He-burning stars younger and more massive than RR Lyrae stars (Clementini et al. 2003b).

We obtained B,V time series photometry of a 33' $\times$ 34' area North to the Fornax dSph center using the WFI@2.2 m ESO-MPI telescope. The selected area contains the globular clusters #3 and #6. We have detected and derived periods for 364 variables in the 2 chips of the

8-CCD WFI mosaic analyzed so far. The vast majority of these variables are RR Lyrae stars, however we also identified Anomalous and Population II Cepheids, and a large number of Dwarf Cepheids (55 objects; Clementini et al. 2004a). We estimate that the total number of variable stars in the area of Fornax we have observed is of about 1000 (lower limit; Maio et al. 2003). This represents the most extensive and deep survey of the variable stars in this galaxy. Figure 5 shows an example of the light curves of the variables in the field of Fornax dSph (left panel) and in its globular cluster # 3 (right panel; see section 1.5.3).

This study is in collaboration with Held (INAF–Padova Obs.), Poretti (INAF–Brera Obs.), Catelan (PUC), Smith (MSU), Pritzl (Macalester Univ.).

The star formation history of Ursa Minor is investigated through the study of the galaxy variable star populations. We are obtaining V, I time series photometry of 3 fields of Ursa Minor with the 1.5m telescope of the Bologna Observatory in Loiano. The selected fields contain 5 of the 7 Anomalous Cepheids known in UMi, and the peak of stellar density that Kleyna et al. (2003) identify with an unbound stellar cluster sloshing back and forth within the UMi halo. This study is in collaboration with Marconi, Ripepi, Musella (INAF–Napoli Obs.).

1.5.3 RR Lyrae stars in globular clusters

People involved at OAB: Bellazzini, Cacciari, Clementini, Baldacci, Maio.

In merging scenarios the Galaxy halo was made up of accreted dwarf Spheroidal Galaxies (dSph's) similar to the known satellite of the Milky Way (MW). A number of GGCs thus may originate from dSph's that were accreted by the MW and should have properties that were directly inherited from their "ancestors". A puzzling feature of the GGCs is that they sharply divide into two distinct Oostheroff types according to the mean periods of their RR Lyrae stars and the relative proportions of fundamental and first overtone-mode pulsators (Oosterhoff 1939). In the MW there are no clusters filling the gap between Oostheroff type I and type II objects. This is not true of the LMC clusters, which instead have mean periods that fill the Oosterhoff gap.

The Galaxy cannot have been assembled from LMC-like protogalactic fragments.

High quality BVI photometric observations were taken in November 2001 of the clusters NGC362 and NGC1904 for a detailed study of their RR Lyrae variables and the second-parameter effect. These data are presently being analysed, in collaboration with M. Catelan (Pontificia Universidad Catolica de Chile).

A very detailed analysis of the RR Lyrae stars in M3 is presently being performed in collaboration with Corwin (Univ. of North Carolina). Based on very accurate multi-colour photometry, this study is showing the impact and characteristics of the Blazhko stars, the presence of a good number of evolved stars and their properties, as well as the characteristics of the main variable star population.

B, V time series photometry reaching half a magnitude below the TO of the remote galactic globular cluster NGC2419 was obtained with DOLORES@TNG. Study of the light curves and pulsation characteristics of the variables is in progress and will allow to check whether this cluster could be the relict of an extragalactic system accreted by the Milky Way. This work is in collaboration with Marconi, Musella, Ripepi (INAF–Napoli Obs.), Di Fabrizio (INAF–TNG).

We are undertaking a systematic study of the variable stars in the 5 globular clusters of the Fornax galaxy to determine their Oosterhoff types and test whether the MW could have accreted GCs from Fornax-like protogalactic systems. 27 RR Lyrae (among which 9 double mode pulsators), 2 Anomalous and 2 Dwarf Cepheids have been identified in Fornax 3 (Clementini et al. 2004a). Examples of their light curves are shown in the right panel of Fig. 5. B, V time series photometry of clusters #2, #4 and #5 was obtained with the 6.5m Magellan/Clay telescope. Figure 6 shows the instrumental color–magnitude diagram of Fornax 5, reaching about 2 mag below the cluster TO. This study is in collaboration with Held (INAF–Padova Obs.), Poretti (INAF–Brera Obs.), Catelan (PUC), Smith (MSU), Pritzl (Macalester Univ.).

Double-mode RR Lyrae stars (RRd's) pulsate simultaneously in the fundamental and in the first-overtone radial modes, while evolving across the HB instability strip. They provide information on the mass, mass-metallicity relation and on the direction and rate of HB evolution. Re-analysis of Corwin & Carney (2001) time series data for the GC M3 using the image subtraction method (Alard 2000), has led to

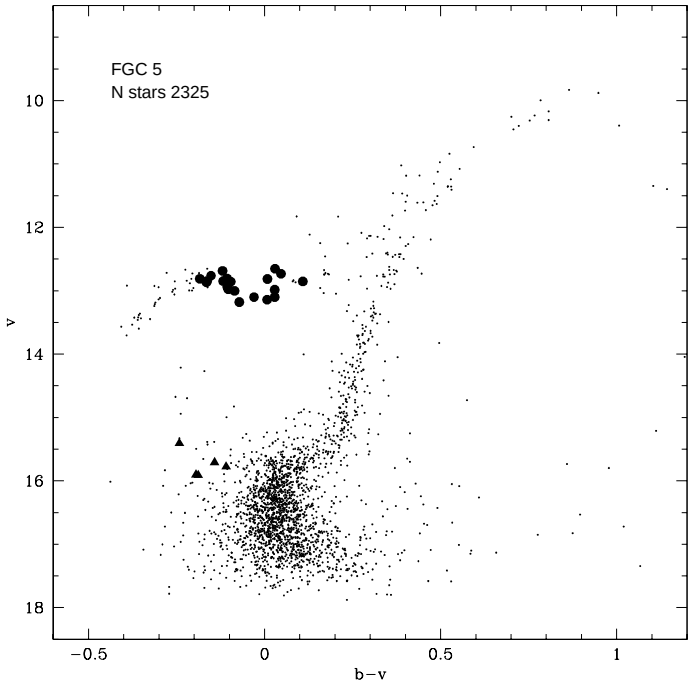


Figure 6: Uncalibrated color-magnitude diagram for the globular cluster For 5 in the Fornax dSph galaxy, based on data obtained with the Magellan/Clay 6.5m telescope and MagIC. Dots are stars belonging to the cluster, large filled circles RR Lyrae variables, and filled triangles candidate binary blue straggler stars.

the discovery of three new double-mode RR Lyrae stars in this cluster. Two of them lie in the Petersen diagram (Petersen 1973), in positions implying large spread in mass and/or heavy element mass fraction among the M3 HB stars. Three of the M3 RRd's have changed their dominant pulsations mode in a one year time-span, thus suggesting that they are undergoing a rapid evolutionary phase, and that both redward and blueward evolution may take place among HB stars. Full discussion of the results is presented in Clementini et al. (2004b). This study is in collaboration with Corwin (Univ. of North Carolina at Charlotte), and Carney (Univ. of North Carolina at Chapel Hill).

1.6 Eclipsing binaries

People involved at OAB: Bonifazi, Lolli.

The study of binary systems is of basic importance to derive fundamental stellar parameters (M, L, R) and therefore to test stellar structure and evolution. For this purpose we have collected light curves of many binary systems observed with the Loiano 60 and 152cm telescopes. We have also derived the precise timing of light minima of the eccentric systems DR Vul, V380 Cyg, RR Lyn, AK Her, ER Vul, BF Aur, exibiting apsidal motion that can be correlated to the mass distribution in the stellar interior. We have observed with the Loiano 152cm telescope the interesting W UMa-type systems RW Com and XY Leo along with the pre-CV NN Ser and the CV TT Ari. Spectra for NN Ser were also collected at the 6m BAT.

Light curve analyses are performed with the Wilson-Price program (Barone et al. 1988) based on the Wilson-Devinney (1971) model. After many tests of the code and some preliminary solutions we proceeded with the study of the binary star XY Leo. This very intriguing W UMa-type system – possibly a triple system – shows unequal maxima. This is explained by the presence of spots on the surface. One of the best solutions is showed in Fig. 7, that displays the observed (open circles) and computed (solid line) light curves.

Our team includes Guarnieri, Bartolini, Piccioni and Cosentino (Univ. Bologna), Beskin (SAO), Milano (Univ. Napoli) and Barone (Univ. Salerno).

1.7 Planetary Nebulae

People involved at OAB: Stanghellini

Planetary Nebulae in the Magellanic Clouds

This project is a major effort started in 1997, aimed to study the morphology and all the nebular and stellar properties of the Magellanic Cloud (MC) PNs. In collaboration with B. Balick (U. of Washington), C. Blades (STScI) and D. Shaw (NOAO) a series of observing programs to probe PN morphology in extra-galactic environments have been successfully executed. We use optical STIS slitless spectroscopy

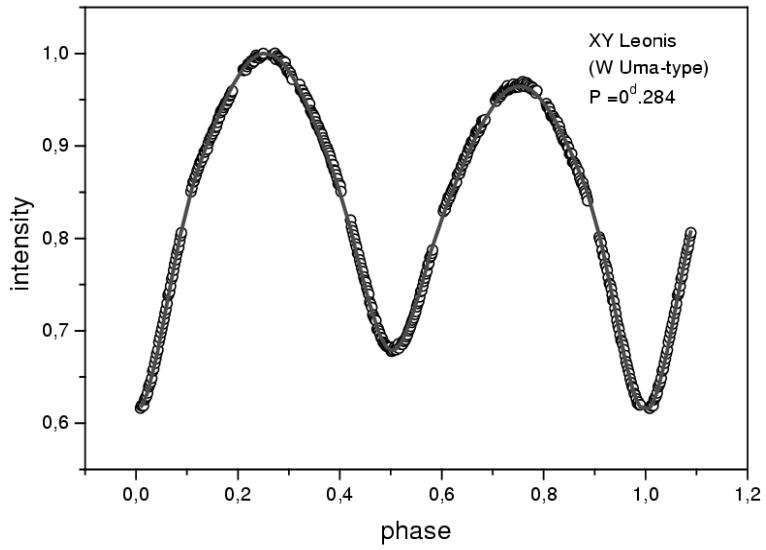


Figure 7: Comparison of observations and solution model for XY Leo, a W UMa binary star possibly consisting of a triple system.

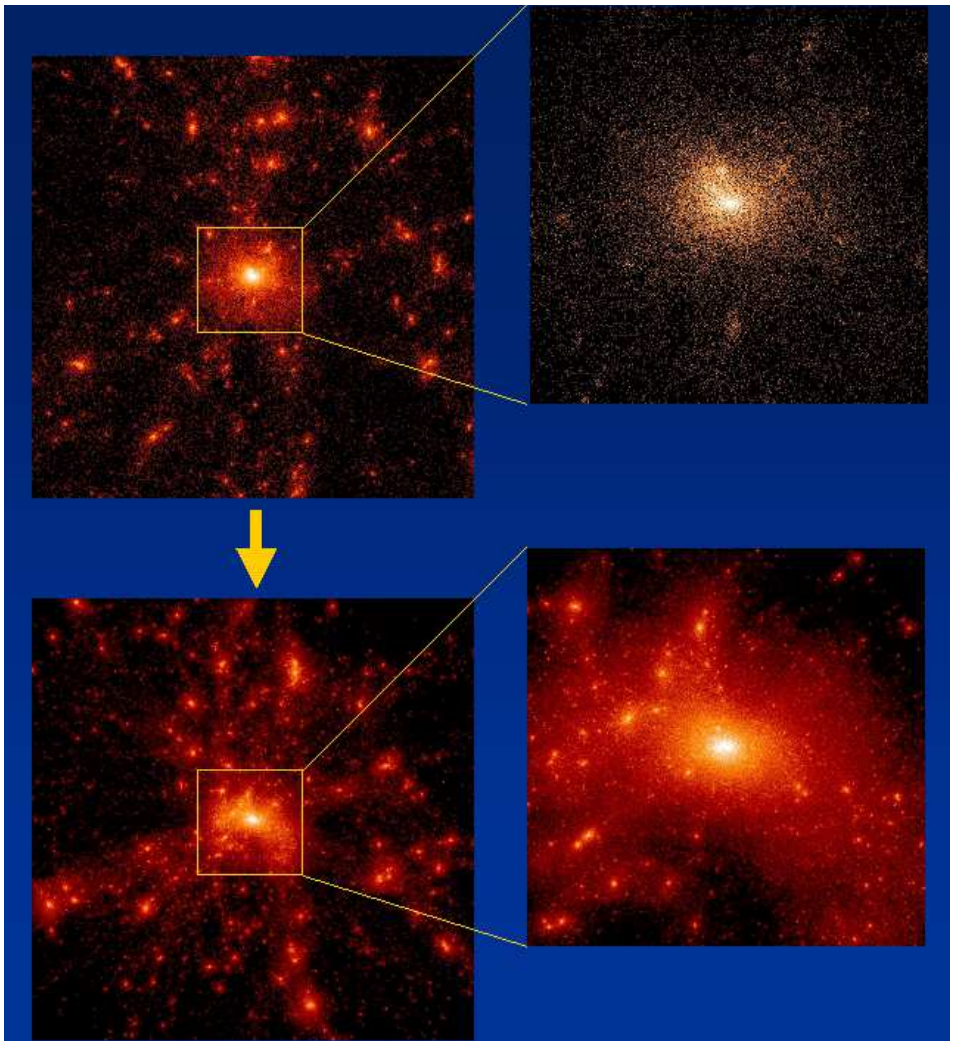
in snapshot mode, obtaining information on multi-wavelength morphology, size, ionization, and central star spectra of about 100 LMC and 30 SMC PNs (about one half the known PNs in those galaxies). Furthermore, we use UV spectroscopy to study the carbon emission and the central star spectra of a subsample of 30 LMC PNs.

Ultra-compact SMC HII regions

Our STIS snapshot survey of SMC PNs was aimed at observing all known (~ 60) PNs previously identified in that galaxy. Given the nature of HST snapshot observations, only 30 targets were actually observed. Of those, two turned out to be misclassified PNs, and are indeed H II regions. An additional H II region was observed within the framework of these observations. A preliminary analysis of these H II regions shows that they are extremely compact (the largest one is less than 3 pc across), extremely reddened (much more than the typical SMC H II region), and well populated star forming regions. Previously, only three very compact H II regions were known in the

SMC (Heydari-Malayeri 1999; Testor 2001), all of them less reddened and compact than those found by us. The importance of studying the ultra-compact H II regions in the SMC is multi-fold. First, they offer an ideal laboratory to study star formation in a low-metallicity environment. Second, the small sizes of these regions, compared to the average SMC H II regions (50 to 270 pc) are indicative of a very recent star formation process (Elmegreen 2000). Third, the low reddening toward the SMC, together with the high resolution of HST, allow us to measure the physical parameters of the ionizing stars, to build the appropriate evolutionary diagrams, and to study star formation at very low metallicity.

2 Extragalactic Astronomy and Cosmology



Example of high-resolution re-simulations. The *upper-left panel* shows the projection of a region of 30 Mpc/h side around a massive (2.3×10^{15} $M_\odot/h$) dark matter halo, obtained in the VLS cosmological N-body simulations carried out by the Virgo Consortium (Yoshida et al. 2001). The *upper-right* panel is a zoom in the 2 r_{vir} (5.4 Mpc/h) region centered on the main halo; the mass resolution is $m_p = 6.68 \times 10^{10}$ $M_\odot/h$, and about 3×10^4 particles are shown in the image. The *lower* panels are the corresponding images in the high-resolution re-simulations: the mass resolution is now $m_p = 2 \times 10^9$ $M_\odot/h$, and more than 10^6 particles are contained within the virial radius of the re-simulated halo. Credit: B. Lanzoni, G. Tormen, V. Springel, G. Mamon, S.D. White.

People involved at OAB:

- *Scientific staff:* S. Bardelli, A. Cappi, P. Ciliegi, A. Comastri, H. de Ruiter, C. Gruppioni, R. Merighi, M. Mignoli, L. Origlia, L. Pozzetti, R. Sancisi, G. Stirpe, G. Zamorani, V. Zitelli, E. Zucca;
- *Fellows:* E. Calabrese, S. Giacintucci, B. Lanzoni, F. Marini, H. McCracken, F. Pozzi, C. Vignali.

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

2.1 Structure and evolution of galaxies

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

2.1.1 Theoretical studies and numerical simulations

People involved at OAB: Cappi, Lanzoni, Zamorani.

N-body simulations of massive DM halos and the formation and evolution of galaxy clusters

Given a sample of 15 massive ($M = 10^{14} \div 10^{15} M_{\odot}$) DM halos, obtained by means of high-resolution N-body simulations in a ΛCDM Universe (B. Lanzoni, PhD thesis), several studies on their properties

and those of their galactic population have been achieved or are still in progress at the Bologna Observatory, and involve collaborations with other national and international institutes.

A detailed analysis of the properties of the substructures of DM halos has been performed by B. Lanzoni with G. De Lucia, G. Kauffmann, V. Springel, S. White (MPA, Garching, Germany), F. Stoehr (MPA), G. Tormen (Astronomy Dept., University of Padova), and N. Yoshida (Harvard-Smithsonian Center forAstrophysics, USA), who also studied a region of mean density. They find that the substructure mass function is almost independent of the mass of the parent halo and is well described by a power-law. Low-mass halos show steeper radial number density profiles of substructures than high-mass halos, and more massive substructures are preferentially located in the external regions of their parent halos. The mass accretion and merging histories of substructures is found to be largely independent of environment, and a significant fraction of the substructures residing in clusters at the present day were accreted at redshifts $z < 1$ (thus implying that a significant fraction of present-day "passive" cluster galaxies should have been still outside the cluster progenitor and more active at $z \sim 1$). Clues on the physical origin of the scaling relations observed for nearby galaxy clusters and elliptical galaxies have been obtained by B. Lanzoni, A. Cappi, G. Zamorani, in collaboration with L. Ciotti (Astronomy Dept., University of Bologna) and G. Tormen (Astronomy Dept., University of Padova). Under the assumption of a reasonable trend of the mass-to-light ratio with the cluster total luminosity, the DM halos are found to reproduce not only the Fundamental Plane, but also the observed luminosity-radius and the luminosity-velocity dispersion relations. Therefore, the scaling relations of galaxy clusters can be explained as the result of the cosmological collapse of density fluctuations and the observed trend of the M/L ratio, while the analogous scaling relations of elliptical galaxies seem to require a non negligible role of merging and gas dissipation during galaxy formation and evolution.

By applying the semi-analytical hierarchical model GalICs (Hatton et al. 2003) to the 15 massive DM halos, B. Lanzoni, in collaboration with J. Devriendt (Lyon Observatory, France), B. Guiderdoni and G. Mamon (IAP, Paris), is studying galaxy formation and evolution in clusters. The comparison with several observed properties of cluster galaxies (luminosity function, color-magnitude relation, morphological fractions, etc.), as well as with the model results obtained for the field

(Hatton et al. 2003) allows us to obtain insights on how galaxies form and evolve, and on how and how much the environment affects their evolution and final properties.

The Fundamental Plane of Elliptical Galaxies

In collaboration with L. Ciotti, and by means of fully analytical galaxy models and Monte-Carlo numerical simulations, B. Lanzoni explored the importance of projection effects in producing the observed thickness of the edge-on Fundamental Plane. They find that the statistical contribution of projection effects to the observed rms thickness is only marginal, while $\sim 90\%$ of it is due to *intrinsic* variations of galaxy properties.

2.1.2 Neutral hydrogen studies

People involved at OAB: Sancisi.

High velocity gas and HI halos of spiral galaxies

R. Boomsma (PhD thesis, Groningen), R. Sancisi, T. van der Hulst (Univ. Groningen), F. Fraternali and T. Oosterloo (ASTRON, Dwingeloo) have continued the study of the vertical structure and kinematics of HI gas in spiral galaxies. Two galaxies have been studied in detail: NGC 6946 and NGC 253. In the direction of the inner disk of NGC 6946 large complexes of high-velocity HI have been detected as well as many HI holes. Both are believed to be caused by the active star formation taking place in the disk. HI holes and high-velocity gas complexes have also been found in the outer parts of NGC 6946, where star formation does not seem to be playing a significant role. These may, therefore, have been produced by other mechanisms such as the collision with infalling gas clouds. Also the starburst galaxy NGC 253 shows HI peculiar features and plumes of gas which apparently extend vertically up to 8 kpc from the plane. This may be related to the starburst taking place in the central regions of the galaxy.

C. Barbieri (Tesi di Laurea, Univ. Milano), F. Fraternali and T. Oosterloo (ASTRON, Dwingeloo), R. Sancisi, and G. Bertin (Univ. Milano) have studied the distribution of mass and the presence of HI (anomalous velocities) in the halo of the spiral galaxy NGC 4559. They have used HI line observations obtained with the Westerbork

radiotelescope. The HI picture obtained from these observations is similar to that of NGC 2403 as derived by Fraternali et al. in recent years. NGC 4559 is kinematically lopsided and shows an asymmetric distribution also in the halo gas.

Galaxy Interactions, accretion, minor mergers

T. van der Hulst (Univ. Groningen) and R. Sancisi have used new HI observations with the Westerbork Radiotelescope to study the tidal interaction and gas accretion in the spiral galaxies NGC 3359 and NGC 4565. These galaxies show HI bridges and tails, clear signs of ongoing tidal interactions with small companions. These are believed to be phenomena similar to the Magellanic Stream and the stellar streamers (e.g. Sgr) discovered in the halo of our galaxy.

Luminous and dark matter in spiral galaxies

G. Battaglia, F. Fraternali, T. Oosterloo (ASTRON, Dwingeloo) and R. Sancisi have completed their study of the HI distribution and dynamics of NGC 5055. This galaxy shows a very large, symmetric warp and a decline of 25 km s^{-1} in the rotation curve, both occurring at about R_{25}. A firm lower limit is derived for the disk mass-to-light ratio in a model with an isothermal halo. This galaxy also shows a peculiar dynamical behaviour: at about R_{25} the systemic velocity changes. A striking geometrical and kinematical symmetrization of the system is obtained by allowing the centre and the systemic velocity to vary. Furthermore, also in NGC 5055 the observations show the presence of HI with anomalous kinematics.

E. Noordermeer (PhD thesis, Groningen), R. Sancisi, T. van der Hulst, T.S. van Albada (Univ. Groningen) and R. Swaters (JHU, Baltimore) have continued the study of early-type disk galaxies (making use of the WHISP database, morphological types Sa and Sb). Rotation curves are derived from the HI data and also from optical spectra. They are found to rise quite steeply in the centre and often to decline significantly in the outer parts. The more recent part of this work consists of the modelling of the contribution of the different mass components in these galaxies to the observed rotation curves. The stellar light distribution is decomposed in a spheroidal bulge and a flat disk component. The stellar disk is needed to explain the rotation curve at intermediate radii, whereas the rotation velocities in the outer regions

can only be explained by the presence of a substantial amount of dark matter. The neutral gas is found to have little or no dynamical impact in these systems. There is a degeneracy between the contributions of the stellar disk and the dark matter, but these early-type disks are certainly not as dark matter dominated as most late-type and dwarf galaxies.

R. Sancisi and R. Swaters (JHU, Baltimore) have continued their study of the luminous and dark matter in the central parts of spiral galaxies. Sancisi (see contribution at IAU Symp. 220, Sydney, 2003) has emphasized the close coupling between the luminous matter and the dark matter in the central regions of spiral galaxies (including LSBs and low-luminosity systems).

2.2 Active galactic nuclei and star-forming galaxies

2.2.1 Optical studies

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

Emission lines and variability of AGN

V. Zitelli and G. Stirpe, in collaboration with D. Trevese (Univ. Rome, La Sapienza), have started a collaboration on photometric and spectroscopic monitoring of high-z quasars using both Loiano and Asiago telescopes. Aim of this research is to study the variability of AGN for both continuum and lines. The different physical processes of emission in both continuum and lines, originating in different regions of the AGN, produce a variability on time scales between 1 week and 1 month for Sy 1 and reaching several months for low redshift QSOs. By means of an intense monitoring of these sources it is possible to estimate the BLR size using the cross correlation among lines and continuum light curves, as found by previous observations. At present correlations are found making use of samples with $M_B > -26$ and the analysis is extended to bright objects by extrapolation. With these observations we aim to obtain for the first time primary estimates of the virial mass and Eddington ratio of high luminosity AGN. Preliminary light curves have been obtained from the first year of data using the observations of both sites. The accuracy of the measurements is $\sim 5\%$, while the variation in luminosity is of the order of 0.1 mag in the CIV and MgII

lines.

Within a collaboration led by A. Marconi (Arcetri Obs.), G. Stirpe is taking part in the monitoring of 2 high-luminosity, high-z QSOs with the ESO VLT, with the purpose of measuring the emission line vs. continuum light curve lag and thus obtain an estimate of the size of the Broad Line Region. These are the highest luminosity AGN monitored in this fashion, which means extending this technique to what are probably the most massive known black holes. Photometric and spectroscopic observations in the K band have been made on a monthly timescale starting in 2001. Light curves have been obtained from the first three years of data. They reveal variations of $\sim$10% in both the continuum and Hα line flux. A preliminary cross-correlation analysis shows that the line vs. continuum lags are between 50 and 200 days. Further monitoring is required to lengthen the time baseline of the light curves and decrease the uncertainties of these estimates.

G. Stirpe, in collaboration with A. Robinson and D. Axon (Rochester Institute of Technology), is studying the distribution of properties of the optical broad emission lines in AGN, covering a wide interval of intrinsic luminosity. In particular, estimates of the central black hole masses have been obtained on the basis of the integrated luminosities and widths of Hα – a newly-developed technique – and indicate that black hole masses in excess of 10^{10} $M_{\odot}$ may be common in high-luminosity AGN.

In collaboration with J. Sulentic (Univ. of Alabama), P. Marziani, R. Zamanov and M. Calvani (Padova Obs.), and V. Braito (Brera Obs.), G. Stirpe has analyzed the Hβ spectra of a sample of high-z QSOs, obtained at the ESO VLT in the near-IR bands. These are the first Hβ spectra taken in the near-IR with quality sufficient to extend to high luminosities and high redshifts the study of the Boroson-Green Eigenvector 1, which correlates various measured properties of the optical emission lines of AGN. The analysis shows that the main spectral characteristics of broad-line AGN are probably not luminosity-dependent.

H. de Ruiter, in collaboration with J. Lub (Leiden Obs.) constructed a database containing many hundreds of photometric and spectroscopic measurements for a sample of about 15 type 1 and type 2 Seyferts in the southern hemisphere, based on fourteen years of observations. These data have now been made available for the general astronomical community: the calibrated spectra can be inspected di-

rectly on the WEB[2], or downloaded (in FITS format). Animations that show the lightcurves of a spectral region around 5000 Å are now available at the same WEBpage.

HST images of B2 radio galaxies

H. de Ruiter, in collaboration with A. Capetti (Torino Obs.), P. Parma and R. Fanti (IRA–CNR, Bologna), and R. Morganti (ASTRON, Dwingeloo), is studying HST images (in two colours, V and I) of about 60 radio galaxies selected from the B2 sample of low luminosity radio galaxies. Brightness profiles were derived for almost all galaxies, and these were used to obtain a detailed mapping of the (circum-)nuclear dust. Fits (with a Nuker law) of the brightness profiles of the B2 radio galaxies have been compared with the profiles of other samples of galaxies (nearby radio quiet ellipticals and brightest cluster galaxies) and have led to the conclusion that radio loud ellipticals have core-type profiles (and not power-laws). This is in line with theoretical studies, which show that merging of massive black holes necessarily produces core-type profiles, and presumably triggers the radio emission.

The environment of AGN

V. Zitelli, in collaboration with P. Focardi and B. Kelm (Astronomy Dept., Univ. of Bologna), is continuing the study of compact groups of galaxies; in particular, the role of active galaxies (AGN) in dense environments is under investigation. Ample evidence has been reported of a complex environment in the local universe around AGN up to $z \sim 3$. However, while it is well established that radio-loud quasars, radio galaxies and BL Lacs 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 V. Zitelli and collaborators adopt a strategy based on the analysis of a statistically significant sample of nearby AGN and of appropriate control samples selected on the basis of criteria independent of morphology and environmental properties. A sample of about 300 physical compact groups has been extracted

[2] *http://www.bo.astro.it/∼deruiter/seyf_spectable.html*

applying an automatic code to 3-D galaxy catalogues. During the current year the occurrence of Seyfert galaxies is being analyzed, in a subsample of these nearby Compact Groups (UZC-CGs) (Kelm et al. 2003). The behaviour of Sy-CGs and non Sy-CGs, when comparing velocity dispersion, number of large scale neighbours and morphological content, shows non-significant differences, though some Seyferts associated to "extreme" CGs present larger velocity dispersion, many neighbours and an unusually high number of elliptical members. Another interesting result from this analysis is that Seyfert 2s are preferentially more associated with compact groups than Seyfert 1s. Previous analyses showed a link between local density and larger scale environment; on the basis of this result it is expected that truly isolated galaxy pairs may display the largest evidence of galaxy interaction. To focus this point a new volume-complete sample of bright isolated galaxy pairs has been extracted using the same algorithm. A preliminary analysis of this isolated galaxy pair sample shows a deficit of luminous dominants among E+E and E+S pairs relative to S+S pairs (Zitelli et al. 2004). Optical observations are in progress using the Loiano telescope to obtain a complete and homogeneous spectral classification, and broad-band two-colour photometry for the whole sample. A post-graduate contract has been assigned for this purpose.

2.2.2 Near-IR studies

People involved at OAB: Comastri, Origlia.

Metal enrichment in starburst galaxies

The near-IR stellar luminosity of starburst galaxies is dominated by massive red supergiants. Such a stellar continuum generally largely dominates over the gas and dust emission (Oliva & Origlia 1998; Origlia & Oliva 2000), while in the visual range the nebular emission strongly dilutes the stellar absorption lines and dust can heavily obscure the central regions where most of the burst activity is concentrated. Their absorption spectra show many atomic and molecular lines which can be used to infer reliable abundances of key metals (e.g. C, O, Fe and other α-elements). Metals locked in the stellar atmosphere of red supergiants trace the abundances just prior to the last burst of star formation. On the other hand, the hot gas in the nuclear region, probed by X-ray observations, is heated by type II SN

explosions and therefore is related to the gas just enriched by the new generation of stars. The X-ray spectra obtained by the new generation of X-ray telescopes (*Chandra* and XMM-*Newton*) have a quality high enough to set good constraints on the metallicity of the hot gas in starburst galaxies and possible spatial gradients. We started with a successful observational campaign at the TNG with NICS, when we secured medium-resolution IR spectra of 4 starburst galaxies observed with *Chandra* and/or XMM-*Newton*, to infer reliable abundances of Fe, C, O, Si, Mg, Ca and Al and to obtain a detailed screening of the most important abundance patterns, namely [C/Fe] and α/Fe], of the pre-burst medium, locked into the stellar photospheres. For the first time detailed stellar abundances in the nuclear region of the starburst galaxy M82 have been obtained. They are compared with those of the hot gas as derived from an accurate re-analysis of the XMM and *Chandra* nuclear X-ray spectra. The cool stars and the hot gas suggest [Fe/H] $= -0.35 \pm 0.2$ dex, and an overall [Si,Mg/Fe] enhancement by $\simeq 0.4$ and 0.5 dex, respectively. This is consistent with a major chemical enrichment by SNe II explosions in recursive bursts on short timescales. Oxygen is more puzzling to interpret since it is enhanced by $\simeq 0.3$ dex in stars and depleted by $\simeq 0.2$ dex in the hot gas. None of the standard enrichment scenarios can fully explain such a behavior when compared with the other α-elements. The analysis of the IR and X-ray spectra of other 3 starburst galaxies is in progress. This work is carried out in collaboration with P. Ranalli (Astronomy Dept., University of Bologna), R. Maiolino and A. Marconi (INAF-Arcetri Obs.).

X-ray number counts and evolution of star-forming galaxies

The fluctuation analysis performed on the *Chandra* deep fields (Miyaji & Griffiths 2001) shows an excess of sources at faint fluxes ($\lesssim 10^{-17}$ erg s^{-1} cm^{-2}) with respect to the predictions of AGN synthesis models for the X-ray background (Comastri et al. 1995). The excess can be explained as the emergence of a population of "normal galaxies". The analysis of well defined samples of star-forming galaxies in the nearby and distant Universe indicates that a linear relation between X-ray and radio luminosity holds up to $z \simeq 1.3$ (Ranalli et al. 2003; Bauer et al. 2002) Since the deepest radio surveys (Fomalont et al. 1991; Richards 2000) show that at faint (sub-mJy) fluxes star-forming galaxies dominate the radio counts, it is possible to use the radio/X-ray relation to transform the observed radio Log$N$–Log$S$ in

predicted X-ray number counts.

The predicted counts are in good agreement with the observed X-ray number counts (for fluxes larger than 5×10^{-17} erg s^{-1} cm^{-2}) and, at fainter fluxes, with the observational limits from the fluctuation analysis in the deepest *Chandra* fields. Similar results are obtained if we consider the IR counts from the ISO ELAIS survey (Gruppioni et al. 2002), or if we integrate the X-ray luminosity function as derived from the radio and far infrared luminosity functions (Machalski & Godlowski 2000; Takeuchi et al. 2003; Sejeant et al. 2004).

This work is carried out in collaboration with P. Ranalli and G. Setti (Astronomy Dept., University of Bologna).

2.2.3 X-ray studies

People involved at OAB: Comastri, Vignali

The large collecting area of XMM-*Newton* has allowed to perform high-quality spectral analysis of the bright narrow-line Seyfert 1 galaxy Ark 564, which was observed twice between 2000 and 2001. The 0.6–10 keV continuum is well described by a soft blackbody component with a temperature of $kT \approx 140$–150 eV plus a steep power law ($\Gamma \approx 2.50$–2.55). The source has shown significant X-ray flux variations (≈ 40–50%) over a time scale of one year, despite the lack of spectral changes. In both observations an absorption edge at a rest-frame energy of ≈ 0.73 keV, corresponding to OVII, has been detected. The XMM-*Newton* data support the idea that the power spectral density shows two breaks, although the location of the high-frequency break requires further constraints. Curiously, the doubly broken PSD resembles that seen in Cyg X-1 in its low/hard state, contrary to the expectation that Ark 564 might look more like the high/soft state (which only shows the high-frequency break).

A significant number of the high-redshift ($z > 4$) quasars discovered by recent optical surveys have been followed-up in the X-rays. These studies have been enabled primarily by the imaging and spectroscopic capabilities of *Chandra* and XMM-*Newton*. From a general perspective, one of the most interesting results is that the X-ray properties of $z > 4$ quasars are similar to those of local quasars. Through a joint X-ray spectral fitting of a sample of 46 radio-quiet quasars (RQQs) with *Chandra* detections in the redshift range 4.0–6.3 (≈ 750 source counts), it has been found that a power law with $\Gamma = 1.9 \pm 0.1$ is

a good parameterization of the rest-frame $\approx$ 3–40 keV continuum. No evidence for widespread X-ray absorption has been found, although some quasars are likely to be obscured. Overall, the emerging picture is that the small-scale X-ray emission regions of quasars appear relatively insensitive to large-scale environmental differences at $z \approx 6$. Similarly to the results obtained for the RQQs, neither the X-ray spectral slope ($\Gamma \approx 1.6 \pm 0.1$) nor the jet emission of the radio-loud quasar population seem to evolve significantly with cosmic time. No evidence for significant X-ray brightening ascribed to inverse Compton scattering of energetic electrons with Cosmic Microwave Background photons has been revealed by snapshot observations with *Chandra*.

The low background, sharp PSF, and sub-arcsec spatial resolution provided by *Chandra* have also allowed the study of the X-ray properties of 6 objects selected from among the OH gigamaser (OHG) sources of the Darling & Giovanelli (2002) sample. This study was aimed at understanding the nature of the engine powering OHGs. The *Chandra* snapshot ($\approx$ 4–5 ks) observations have allowed us to place constraints on the relative contribution between the AGN and starburst emission. None of the sources has been detected in the X-ray band; this is consistent with the hypothesis that most of the power in OHGs comes from a starburst, although it is not possible to rule out, at least in some objects, the presence of Compton-thick (i.e., $N_{\rm H} > 10^{24}$ cm^{-2}) absorption.

The superb imaging capabilities of *Chandra* have been further exploited to study the complex nuclear and extended emission (lobes and jets) of the high redshift radio galaxy 3C 265. The heavily absorbed nuclear luminosity provides, together with the microwave background radiation, the seed photons which are upscattered by inverse Compton with the relativistic electrons in the lobes in the X-ray band. A detailed analysis of the physical properties of the jets and lobes is ongoing.

2.3 Surveys and Observational Cosmology

A large fraction of the Observatory staff is involved in surveys of extragalactic objects[3]. Some of these surveys are ongoing long-term

[3]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 red-

projects, but quite a few have started only recently, or will start in the near future, and will require telescope time with new generation optical telescopes like the VLT.

2.3.1 The VIRMOS/VLT Deep Survey (VVDS)

People involved: Bardelli, Cappi, Ciliegi, Merighi, McCracken, Pozzetti, Zamorani, Zucca.

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

The visual spectrograph VIMOS[4] is mounted at VLT-Melipal and saw its first light successfully on February 26, 2002. Commissioning and testing were completed in 2002 and the guaranteed time observations started in Autumn 2002.

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

shift. In many cases the solutions are given in analytical form. The compendium can be found on the WEB: *http://www.bo.astro.it/∼deruiter/cosmo/.*

[4] *http://www.astrsp-mrs.fr/virmos/index.html*

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

In particular, during the year 2003 the researchers at the Observatory involved in the VVDS have worked and contributed to the following topics:

• Observations and data reduction which have led to the public release (in 2004) of about 1600 redshifts to $I_{AB} \leq 24$ across the *Chandra* Deep Field South.
• Production of the photometric multiband ($BVRI + K$) catalogues which are the starting point of the spectroscopic survey. Various tests have been applied to these catalogues in order to verify the quality of the data.
• Development of tools for the scientific analysis of the survey: in particular for the luminosity function analysis, with the implementation of different estimators and testing their statistical robustness on simulated samples with different completeness (Ilbert et al. 2004).
• Comparison of different cluster-finding methods, applying the algorithms on simulated samples (Rizzo et al. 2004).
• Preparation of the tools which will be used in the statistical analysis of the galaxy distribution, in particular the correlation function and high-order statistics.
• Preparation of different models of galaxy evolution in the framework of a Pure Luminosity Evolution (PLE) scenario to be used for the comparison with the observed galaxy redshift distribution.

The first epoch data (to $I_{AB} = 24$) have been used to derive the luminosity function in different bands up to $z \sim 1.5$. The global luminosity function has been estimated in different redshift bins, using various estimators (see Fig. 8), revealing an overall brightening of this function by ~ 1.5 magnitudes at $z \sim 1$, with a significant strong steepening of the faint end slope.
Given the large number of galaxies, it is possible to follow the evolution of the luminosity function for the different galaxy spectral types. All galaxies have been classified in four types, from early-type to blue star forming galaxies: while the luminosity function of the early-type

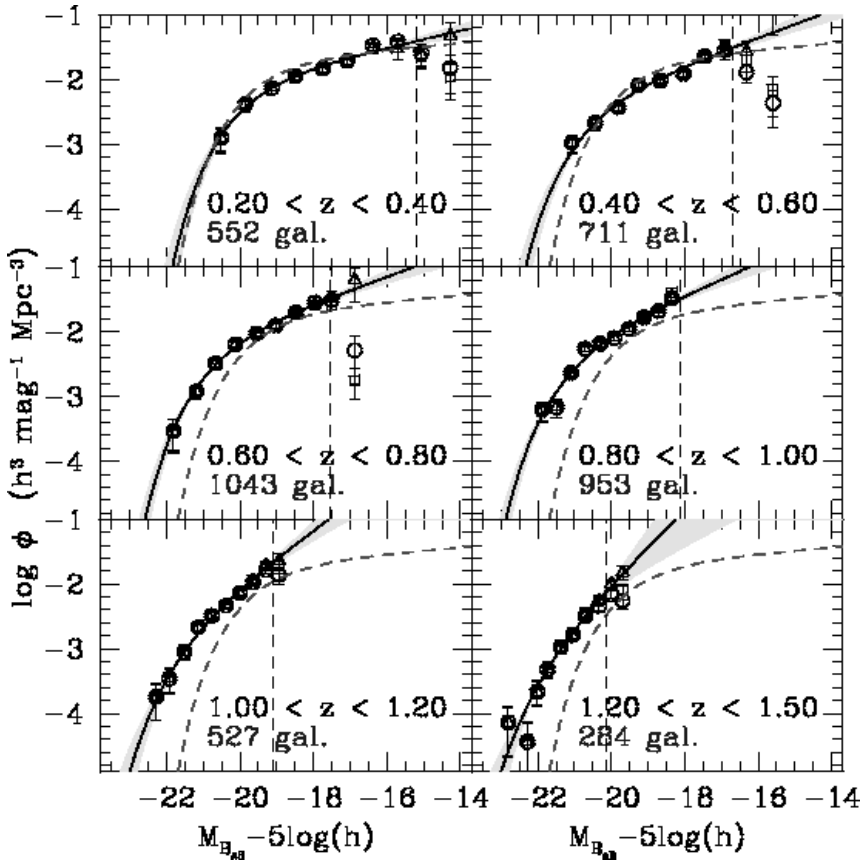


Figure 8: Luminosity function in the B band (rest frame) for galaxies from the first epoch VVDS, derived with various estimators: $1/V_{max}$ (open circles), C^+ (open squares), SWML (open triangles) and STY (solid line). The grey area represents the 1σ uncertainties for the STY estimate. The dashed line represents the local estimate from the Sloan Digitized Sky Survey.

population does not seem to evolve by more than ~ 0.5 magnitudes, the function of the blue star forming galaxies is strongly evolving with redshift.

2.3.2 The VIRMOS RADIO survey

People involved: Ciliegi, de Ruiter, Zamorani.

The radio survey has been obtained with the VLA at 1.415 GHz in one of the VIRMOS region where deep $BVRI$ band photometry was already available (from CFHT observations) to a limiting magnitude (5σ) of about 25.5 and, for a fraction of the area, in the U and K bands with the ESO telescopes to a limiting magnitude of 25 and 20 respectively. The VIRMOS VLA radio survey has mapped an area of 1 square degree with a uniform noise of $\sim 85\,\mu$Jy (5σ). A catalogue of radio sources brighter than the local 5σ threshold has been extracted from the 1 degree radio map. It contains 1054 radio sources, 19 of which are considered as multiple, i.e. fitted with at least two separate components. The source counts of this radio catalogue are in very good agreement with those of other surveys. In particular, our point at the faintest flux level (~ 0.1 mJy) is fully consistent (with more robust statistics thanks to the higher number of sources and a large area covered) with the points obtained with a very deep radio observation in the Hubble Deep Field (HDF). A detailed description of the VIRMOS RADIO survey is reported in the paper Bondi, Ciliegi, Zamorani et al. 2003.

Subsequently, using the already available optical data, we performed a detailed optical identification using a Likelihood Ratio Analysis. We found ~ 730 reliable optical counterparts. The expected number of spurious identifications is ~ 40 leading to an identification percentage of $\sim 70\%$.

The colour properties of the optical counterparts of the radio sources have been analysed using the $(B-V)$ and $(V-I)$ colours. The optical counterparts of the radio sources classified as extended have been analysed in three different magnitude slices. While in the brightest magnitude range ($18 < I_{AB} < 20$) the optical colour properties of the radio sources are not different from those of the whole optical sample, at fainter magnitudes the median colour of the radio sources is redder than the median colour of the whole optical sample, probably indicating a higher redshift for the radio sources.

2.3.3 The K20 Redshift Survey

People involved at OAB: Lanzoni, Mignoli, Pozzetti, Zamorani.

The Bologna Observatory participates, with the observatories of Arcetri, ESO and Rome, in an ESO VLT Large Program (PI Cimatti, Arcetri Obs.), which started in 1999. This program (called K20[5]) aims at deriving the redshift distribution of a galaxy sample complete at $K < 20$ in order to obtain stringent clues on the formation and evolution of present-day massive galaxies (Cimatti et al. 2002). The sample consists of 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 observations were completed in 2000. In addition, ultradeep spectroscopy was obtained in November 2002 with FORS2 to derive information on previously unidentified EROs and $z > 1.7$ galaxies. We have provided spectra of 92% of the galaxies down to a completeness level of about $K < 20$. Moreover, the K20 survey is triggering several follow up studies in which we are involved. High resolution spectroscopy (PI Cimatti) was recently obtained with FORS2 to study the kinematics of $z > 1$ galaxies in order to estimate their dynamical masses. The CDFS sub-area of the K20 survey is also a target of the HST+ACS GOODS Treasury Programme (PI Giavalisco) and of the SIRTF GOODS (PI Dickinson) Legacy Programme.

The scientific analysis is still in progress and the main results obtained up to now can be summarized as follows (details can be found also in the previous reports):

- A major result was the discovery of a significant high-redshift tail (32% and $\sim 9\%$ of galaxies at $z > 1$ and $z > 1.5$ respectively), not consistent with current versions of hierarchical models of galaxy formation (Cimatti, Pozzetti et al. 2002).

- We have obtained, for the first time, a spectroscopic sample of EROs. We found that the two classes of old and dusty star-forming galaxies in the ERO population, based on both spectroscopic (Cimatti et al. 2002) and HST morphological properties

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

obtained from GOODS images (Cimatti et al. 2003), are about equally populated. Conversely they show very different stellar populations, as well as different clustering and correlation length.

- We have carried out the analysis of the near-IR (J and Ks band) Luminosity Functions down to redshift ~ 1.9 (Pozzetti et al. 2003). The data are consistent with a *mild luminosity evolution*, in particular, *red and early-type galaxies dominate the bright-end of the LF*, and their number density shows at most a small decrease ($< 30\%$) up to $z \simeq 1$, thus suggesting that massive elliptical galaxies were already in place at $z \simeq 1$ and *they should have formed their stars and assembled their mass at higher redshift.* Current versions of hierarchical models (Cole et al. 2000; Kauffmann et al. 1999) significantly overpredict the density of low luminosity galaxies at $z \leq 1$ and underpredict the density of luminous galaxies at $z \geq 1$, whereas passive evolution models are more consistent with the data up to $z \sim 1.5$.

This year we have completed, in collaboration with the Rome Observatory, the study of the Galaxy Stellar Mass Function and its evolution to $z \simeq 2$ (Fontana, Pozzetti et al. 2004, in press). We found that the typical mass-to-light ratio of massive early type galaxies is larger than that of less massive ones, suggesting that their stellar population formed at higher z. The final K20 galaxy sample spans a range of stellar masses from $10^9 M_\odot$ to $10^{12} M_\odot$: massive galaxies ($\geq 10^{11} M_\odot$) are common at $0.5 < z < 1$, and are detected also up to $z \simeq 2$. The Galaxy Stellar Mass Function shows only a mild evolution (i.e. by 20–30%) up to $z \simeq 1$. At $z > 1$, the evolution in the GSMF appears to be much faster: at $z \simeq 2$, about 35% of the present day stellar mass in objects with $M_* \simeq 10^{11} M_\odot$ appears to have assembled. Moreover we found that at $z < 0.7$, all galaxies with $M > 10^{11} M_\odot$ are early type, while at higher z a population of massive star-forming galaxies progressively appears. The predictions from hierarchical models range from severe underestimates to slight overestimates of the observed mass density at ≤ 2 (see Fig. 9).

From ultradeep spectroscopy we have furthermore investigated the population of $z > 2$ galaxies (Daddi et al. 2004). We found a new population of massive galaxies, with HST irregular morphology, and with multi-band photometry and average spectrum consistent with high star formation rate absorbed by a large amount of dust, young stellar populations and high metallicity (De Mello et al. 2004, in press).

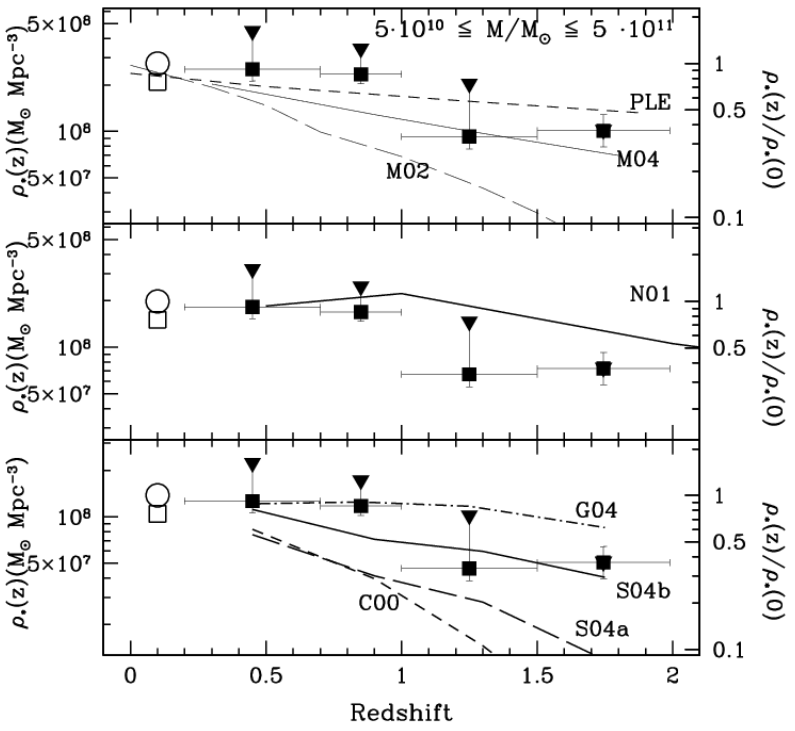


Figure 9: Cosmological Stellar Mass Density for objects of $M_* \simeq 10^{11} M_\odot$ in the K20 survey (Fontana et al. 2004, in press), compared with the theoretical models, divided according to the relevant IMF: *upper panel*: Salpeter (1955), *central panel:* Gould et al. (1996), *lower panel:* Kennicutt (1983). Filled squares and filled triangles represent different Mass estimates. The empty circle and square at $z = 0.1$ represent the local values of Cole et al. 2001. The models plotted are: Menci et al. 2002 (M02), Menci et al. 2004 (M04) and Pozzetti et al. 2003 (PLE) in the upper panel; Nagamine et al. 2001 (N01) in the central panel, and Cole et al. 2000 (C00), Somerville et al. 2004a (S04a and S04b) and Granato et al. 2004 (G04) in the lower panel. The relative value with respect to the local value of Cole et al. 2001 is shown in the right-hand y-axis.

This population is consistent with being the progenitor of massive local ellipticals.

At present, in Bologna, we are completing the analysis of the spectroscopic K20 sample, both studying the properties of the single object spectra, and constructing average templates for different spectral classes and/or different redshift bins, with the aim of characterizing a possible spectral evolution. In addition, we are collaborating with Arcetri in the study of the star formation history using different SFR indicator ([OII], Hα, UV flux) up to $z \simeq 1.5$.

Finally, in collaboration with the Arcetri Observatory (Alighieri, Cimatti, Vernet) we are involved in the analysis of the high resolution spectra of a subsample of early and late type galaxies at $z \simeq 1$, recently obtained. In particular we are carrying out the spectral analysis of early type galaxies using high resolution model templates (Bruzual & Charlot 2003) to derive new constraints on their stellar population and on the epoch of formation of massive elliptical galaxies. Moreover, we are comparing the dynamical properties, derived from high-resolution spectra of both elliptical and spiral galaxies, with those obtained by the hierarchical model GalICs (Hatton et al. 2003). From observations we found well defined scaling relations, as the Tully-Fisher and the Fundamental Plane. Preliminary results show that model galaxies define scaling relations similar to those observed, even if the zero point and scatter appear not to be exactly the same. A more detailed comparison and the interpretation of results in terms of the capability of the hierarchical scenario in describing galaxy formation is still in progress.

2.3.4 Radio observations of the ESP Survey

People involved at OAB: de Ruiter.

The ATESP catalogue contains about 3000 radio sources down to a 20 cm flux limit of ~ 0.4 mJy. The radio data (including new data at 5 GHz) are 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. Spectroscopy of part of the fainter objects

has recently been carried out with the VLT and analysis of the spectra is in progress.

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 $+30^{o}$) at 325 MHz (and is complementary to the NVSS survey at 20 cm made by the VLA). The overall catalogue contains about 200000 radio sources with flux density above 15 mJy. Work is in progress at the 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 available; the final list is expected to be available by the end of 2004. Several spin-off programmes are in progress: a number of possible relic radio sources (characterized by a steep radio spectral index) were selected for further study with the VLA at different frequencies. The new information on the radio structure and the spectral index confirms that two of the three sources are indeed fossile sources, while the third is a fossile source in which the radio activity has restarted.

2.3.6 X-ray Surveys

People involved at OAB: Ciliegi, Comastri, Mignoli, Pozzetti, Zamorani.

The HELLAS2XMM survey

The `HELLAS2XMM` survey is a large national project carried out in collaboration with several Italian institutes (INAF–Arcetri and Rome Obs., Rome 3 Univ. and IASF–CNR, Milan). The final scientific aim of this project is the evaluation of an accurate luminosity function over a wide range of redshifts and luminosities for a large sample of hard X-ray selected sources detected in 15 public XMM-*Newton* observations, covering an area of about 4 square degrees at relatively shallow hard X-ray fluxes ($F_{2-10\,\mathrm{keV}} > 10^{-14}$ erg cm^{-2} s^{-1}). This survey strategy has been designed to be complementary to deep pencil beam surveys by sampling a different portion of the luminosity–redshift plane in order to fill the gap between the local and deep surveys and to obtain

a complete measure of the density and evolution of X-ray selected AGN.

To date, the most important results from the HELLAS2XMM project are mainly related to the optical identifications and spectroscopic classifications of a sample of 122 sources detected in $\sim$1 deg^2 (Fiore et al. 2003), obtained from an extensive campaign of multiwavelength observations and the full exploitation of the ESO and TNG facilities (e.g. EFOSC2 at the 3.6m telescope in La Silla; FORS2 at the VLT telescope; DOLORES at TNG). At the same time several multiwavelength (radio, sub-mm and near infrared) follow-up programs have been or are being carried out on a fraction of these fields. For two specific fields high spatial resolution *Chandra* X-ray data are also available. The optical campaigns have provided optical identifications and spectroscopic classifications for 97 out of the 122 hard X-ray selected sources; the spectroscopic completeness of the sample ($\sim$80%, mainly limited by the faintness of the optical counterparts, $R \gtrsim 24$) is one of the highest for sources detected at flux level $\gtrsim 10^{-14}$ erg cm^{-2} s^{-1}.

Given the relatively bright X-ray fluxes sampled, an accurate X-ray spectral characterization was achievable for almost all of the sources in the sample. Out of these, 106 sources with 86% spectroscopic redshift were used to evaluate the fraction of X-ray absorbed ($\log N_H > 22$) AGN at these limiting fluxes, and to compare it with that predicted by X-ray background synthesis models (Perola et al. 2004).

A detailed study of a specific field (the PKS 0312$-$77 field) for which *Chandra*, radio and near-infrared data were also available, has clearly pointed out the importance of multiwavelength, high spatial resolution observations to fully characterize the physical properties of hard X-ray source counterparts (Brusa et al. 2003). The overall picture emerging from the optical identifications of the HELLAS2XMM sample indicate a wide spread in the optical (both in the continuum shape and emission lines) and X-ray properties of the sources responsible for the bulk of XRB energy density. The optical appearance of hard X-ray selected AGN is different from that expected on the basis of the AGN Unified Scheme, calling for some revisions to account for the discrepant classifications. In particular, the combination of X-ray spectral analysis and deep VLT spectroscopy has revealed that $\sim 10\%$ of high-redshift, high-luminosity objects optically classified as unobscured BL AGN are absorbed in the X-rays by column densities in excess of 10^{22} cm^{-2} (Brusa et al. 2003; Perola et al. 2004).

What can be considered the most surprising and relevant finding

of the HELLAS2XMM survey is the discovery of a population of presumably obscured AGN which are characterized by values of their X-ray (in the 2–10 keV band) to optical (integrated over the R filter) flux ratio (X/O$>$ 10), significantly different from those of optically and soft X-ray selected, spectroscopically identified AGN.
We have provided, for the *first time*, spectroscopic identifications (using VLT/FORS2 data) of a sizable sample (13) of high X/O sources from the HELLAS2XMM sample. The majority of these turned out to be spectroscopically classified as high luminosity, high redshift narrow-line quasars (Fiore et al. 2003). Different approaches to estimate the redshift of optically faint X-ray sources have also been developed and tested for the sources detected in the deepest *Chandra* exposures: in particular, it was possible to derive the redshift of highly obscured objects by detecting a strong Fe Kα line in a few high S/N X-ray spectra of sources detected in the deepest *Chandra* fields (Comastri, Brusa & Civano 2004).

Combining the results from the HELLAS2XMM survey with those obtained from deep, pencil-beam *Chandra* and XMM-*Newton* surveys, it was possible to build a "virtually complete" sample of identified hard X-ray sources over a wide range of redshifts and luminosities. We have clearly pointed out the need for a luminosity-dependent density evolution for the sources responsible for the XRB (low luminosity sources peaking at a later cosmic time), to explain the observed number and luminosity densities as a function of redshift (Fiore et al. 2003). With this assumption, and the hypothesis that hard X-ray surveys probe the largest fraction of the whole AGN population, it is possible to explain the observed local BH mass density as entirely due to the growth of AGN (Comastri 2003).

For a selected subsample of 10 high X/O sources in the HELLAS2XMM survey, undetected in the optical band, deep VLT/ISAAC imaging has been obtained: almost all of the observed sources (10/11) were detected in the K-band and their optical to near-infrared colors are considerably redder than those of the field galaxy population, all of them being classified as Extremely Red Objects (Mignoli et al. 2004). Thanks to the quality of the near-infrared data a detailed analysis of the surface brightness profiles allows us to classify all of the near-infrared counterparts: the majority of these (7) have been classified as elliptical (bulge) galaxies, two as pointlike objects and one source with an exponential profile (disky). The results of the fit of the extended sources are reported in Fig. 10. None of the extended sources show

any evidence for the presence of a central unresolved object tracing the putative X-ray emitting AGN.

Coupling the morphological information derived from K-band surface brightness profiles, it was possible to derive a "minimum" redshift for these objects ranging between 0.8 and 2.4; in particular, the elliptical hosts have $z_{\rm min} = 0.9$–1.4. The X-ray spectral properties of these sources indicate that heavy ($N_H > 10^{22}$ cm^{-2}) obscuration is almost ubiquitous among objects with high X/O and that obscured sources (in particular QSO2, the high-luminosity, high-redshift obscured AGNs predicted in XRB synthesis models) can be hosted in the bulge of luminous, massive ellipticals which already formed the bulk of their stars at high redshifts.

This work is carried out in collaboration with M. Brusa (Astronomy Dept., University of Bologna).

XMM-*Newton* observations of Extremely Red Objects

Hard X-ray observations of Extremely Red Objects (EROs) with XMM-*Newton* have been carried out in one of the largest samples of EROs available to date (Daddi et al. 2000), selected in a contiguous area of ~ 380 arcmin^2. We have obtained a total of 100 ks of XMM-*Newton* data, split between two observations. This work provides the first comprehensive characterization of the X-ray properties of a large sample of individually detected EROs. It was possible to estimate for the first time, over a large statistically significant sample of objects, the fraction and the X-ray spectral properties of AGN among EROs. The results obtained from the cleaned 80 ks XMM-*Newton* observation suggest that, at the relatively bright X-ray and near-infrared fluxes probed by this observation, AGN account only for a negligible fraction (3%) of the optically selected ERO population (Brusa 2003).

The X-ray and optical properties of individually detected EROs are similar to those of Quasars 2, the high-luminosity, high redshift type II AGNs predicted in XRB synthesis models. The somewhat unexpected link between EROs and QSO2, is intriguing: near-infrared observations of obscured QSOs selected on the basis of their high X/O (e.g. from the `HELLAS2XMM` sample, see above) and, conversely, hard X-ray observations of a complete sample of EROs, provide some of the strongest evidence that these two populations, originally discovered at

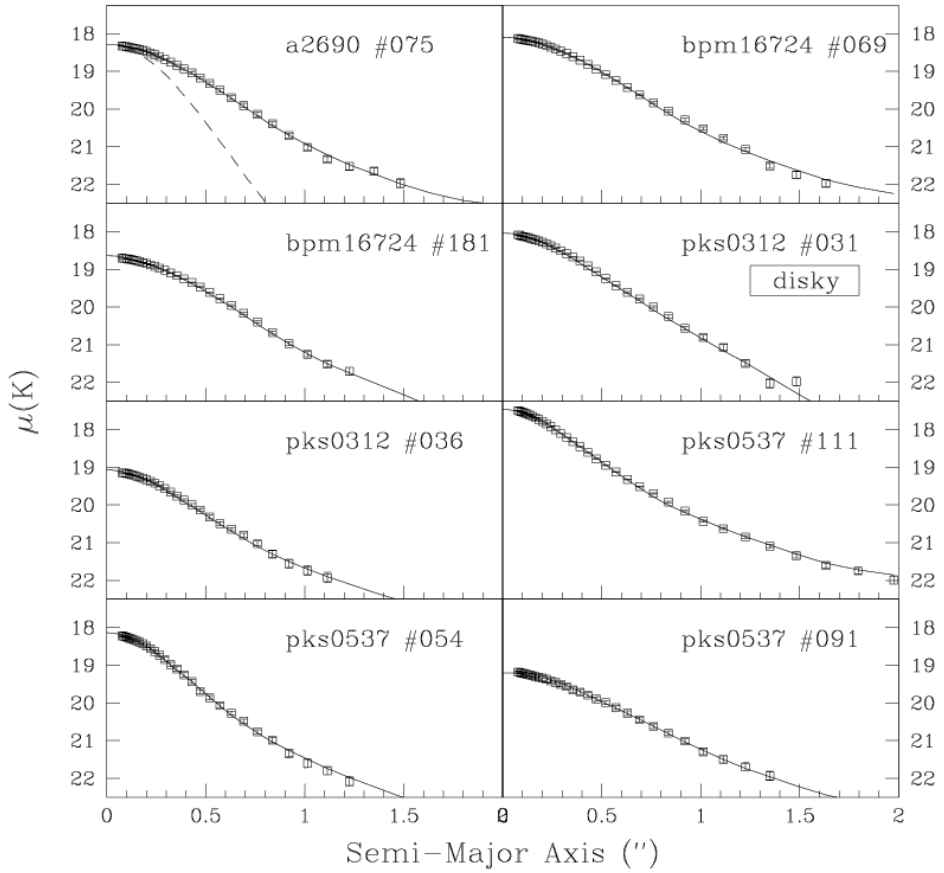


Figure 10: Surface brightness profiles along the major axis (boxes) and best-fitting models (lines) for all of the extended sources in the HELLAS2XMM sample for which VLT/ISAAC observations have been obtained. In the upper left box we also show with a dashed line a representative PSF.

different wavelengths, are intimately connected.

A selection criterion based on the X/O and the $R - K$ colour of hard X-ray selected sources has been proposed, to efficiently pick up the elusive QSO2 population, which is difficult to select at optical wavelengths. Furthermore, X-ray detected EROs can be used as lighthouses to investigate the accretion paradigm at high redshifts, in order to address the issue of elliptical galaxy formation and the expected coevolution with accreting black holes. Our work clearly indicates that the combination of near-infrared and X-ray observations is a powerful tool to select this so-far elusive population of luminous, obscured X-ray sources. These results have allowed to obtain *Chandra* data (90 ks) on the ERO field, to push the X-ray analysis to fainter fluxes.

This work is carried out in collaboration with M. Brusa (Astronomy Dept., University of Bologna).

2.3.7 The ELAIS Survey

People involved at OAB : Calabrese, Ciliegi, Comastri, Gruppioni, Mignoli, Pozzetti, Pozzi, Zamorani.

ELAIS is a large European project, involving 19 different institutes, initially aimed at studying the nature and evolution of the extragalactic sources detected by the Infrared Space Observatory (ISO) in selected areas of the sky. At present the collaboration has enlarged and the survey coverage has extended to other wavelengths, so that now the ELAIS southern area S1 (4 square degrees) is one of the best studied due to its extensive multiwavelength coverage.

In fact, this field is one of the main selected fields of the largest survey performed with ISO (ELAIS, covering 12 sq. deg. at 15 μm): its size is 4 sq. deg. and the 15 μm catalogue published by Lari et al. (2001) contains 329 extragalactic sources over the flux range 0.5–100 mJy. The entire area is covered by radio observations obtained with the ATCA down to $S_{1.4-\mathrm{GHz}} \simeq 0.2$ mJy (Gruppioni et al. 1999), which C. Gruppioni, F. Pozzi, P. Ciliegi and G. Zamorani, in collaboration with C. Lari (IRA–CNR Bologna), F. La Franca (Università di Roma3) and I. Matute (MPI) have used to investigate and derive the radio-IR correlation for the first time at those flux densities and for a sample of that size (~ 100 ISOCAM-radio associations with measured z; Gruppioni, Pozzi, Zamorani, Ciliegi et al. 2003).

S1 is also covered by R-band CCD exposures reaching $R \sim 23$ (obtained at the ESO/Danish 1.5m telescope in collaboration with F. La Franca, I. Matute, C. Lari et al.), where 82% of the IR extragalactic sample have a likely counterpart. Two main spectroscopic classes are found to dominate the MIR extragalactic population: star-forming galaxies mainly at $z < 0.5$, which account for $\approx 75\%$ of the sources, and Active Galactic Nuclei (AGN; both type 1 and 2), which account for $\approx 25\%$ of the sources (La Franca, Gruppioni et al. 2004)

Again in the framework of the follow-up of the ELAIS region, F. Pozzi, E. Calabrese, P. Ciliegi, C. Gruppioni, M. Mignoli and G. Zamorani (in collaboration with C. Lari, and P. Heraudeau (Groningen)) have studied the optical, near-IR and radio properties of the complete sample of 43 sources detected at 15 μm in the ELAIS field S2, where about 90% of the sources (39 out of 43) have optical counterparts brighter than $I = 21$. The 15-μm, Hα and 1.4-GHz luminosities have been used as different indicators of star-formation rate in galaxies (Pozzi et al. 2003).

F. Pozzi, C. Gruppioni and G. Zamorani, in collaboration with S. Oliver (Sussex Univ.), I. Matute, F. La Franca, C. Lari, A. Franceschini (Univ. of Padova) and M. Rowan-Robinson (ICSTM), have obtained the first direct determination of the 15-μm luminosity function and its cosmic evolution for galaxies from the ELAIS survey. The analysis is based on $\sim$150 ELAIS galaxies in the redshift interval $0.0 \leq z \leq 0.4$, covering a large flux density range, intermediate between IRAS and the deep ISOCAM surveys (0.5–50 mJy). Strong evolution (of the order of $(1+z)^{3.5}$ both in luminosity and in density) is suggested by our data for the starburst galaxy population, while normal spiral galaxies are consistent with no evolution. The model predictions have been compared with other observables, like source counts at all flux density levels (from 0.1 to 300 mJy) and redshift distributions and luminosity functions at high-z ($0.7 < z < 1.0$ from HDF-N data), showing a remarkably good agreement. Using the evolutionary model found for the 15-μm galaxies and the data points from the $1/V_{max}$ LF analysis, we have estimated the star-formation rate density up to $z \sim 1$. At $z \leq 0.4$ our model predictions are well consistent with other estimates derived from UV, optical and MIR data. At higher redshifts our model predictions are significantly higher than the UV extinction corrected data and lower by about a factor of two than the estimates derived from radio data (Pozzi, Gruppioni et al. 2004).

The ELAIS area S1 is one of the targets selected by the *Spitzer* legacy programme SWIRE (PI C. Lonsdale (Caltech)) and will be observed in June 2004. The SWIRE project is the largest Survey project that will be performed with *Spitzer*, covering a total of about 70 sq.deg. (10 of which on the S1 region) at all available wavelengths (from 3 to 200 μm). Our 15-μm ISOCAM data will be of extreme importance for calibrations and interpretation of the *Spitzer* data, since they will fill the gap between the short- (IRAC: 3.6–8μm) and long-wavelength (MIPS: 24–160μm) instruments on board *Spitzer*.
In the framework of the SWIRE collaboration, we have obtained deep B, V and R images with the WFI at the ESO 2.2m telescope (ESO Large Programme ESIS: PI A. Franceschini) down to about $B = 24.7$, $V = 24.0$ and $R = 24.5$ and in the I and Z band with VIMOS-VLT. Moreover, about 1 sq. deg. of S1 has been covered by deep $K^{'}$ band exposures with SOFI at the ESO NTT telescope (ESO Large Programme: PI A. Cimatti (INAF–Arcetri Obs.)) and in the X-ray band with XMM-*Newton* (4 pointings of about 100 ksec each have been obtained in the central area of S1: PI F. Fiore (INAF–Rome Obs.)) with about 500 sources detected in the 0.5–10 keV band down to a flux of 2–3 $\times 10^{-15}$ cgs.
Recently, a new very deep radio observation at 1.4 GHz has been obtained with the Australia Telescope Compact Array (ATCA) (PI : Boyle, CoI: Ciliegi, Condon, Lonsdale) in the ELAIS region S1 down to an rms noise of 10 μJy. The data have been collected in January and February 2004 and the data reduction is ongoing.
Finally, 30 hours at the ESO VLT telescope with the VIMOS spectrograph have been allocated in the ELAIS S1 field (PI: F. La Franca) with the aim of obtaining spectroscopic identification for the fainter 15-μm ISO sources, for the new XMM and $K^{'}$ sources and for the radio sources obtained with the new ATCA data.

2.4 Galaxy clusters and large-scale structure

2.4.1 Merging clusters in the core of superclusters

People involved at OAB: Bardelli, Cappi, Giacintucci, Marini, 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 investi-

gating the effects of the environment and of the merging phenomena on the physics of clusters and on their galaxy population. In particular, the central parts of superclusters are ideal laboratories in which to study dynamical processes, given the high peculiar velocities induced by the density excess.
We focused our attention on the three structures formed by interacting clusters (the A3558 complex, the A3528 complex and the A3571 complex) which dominate the core of the Shapley Concentration. In particular from all our data and analyses we concluded that these complexes are part of an evolutionary sequence: the A3528 complex is at the very beginning of a merger event, where the two merging entities have just started "to feel each other"; the A3558 complex is thought to be an advanced merger, where two clusters of similar mass have already undergone the first core–core encounter; the A3571 complex represents the final stage of a merger event, where A3571 itself is the resulting cluster after virialization of the merger.

The main results of this work in the year 2003 were the following:
• In the last years we performed an extensive radio survey in the region of the three cluster complexes, in order to find the effects of major merging events on the radio emission of the galaxy population. The most remarkable result was a significant deficiency of radio galaxies in the A3558 complex (Venturi et al. 2000), consistent with an ongoing merge. In order to better investigate this point we performed a deeper survey in the region of A3562 and SC1329-131 at 1.4 GHz, in the A3558 complex (Giacintucci et al. 2004). We confirmed the presence of a radio halo and of a head-tail radio galaxy at the centre of the cluster A3562. We performed a detailed radio multifrequency study of the head-tail galaxy, which is completely embedded in the halo emission (Venturi et al. 2003). The radio halo has an irregular shape, and a largest linear size of ~ 620 kpc, which is among the smallest found in the literature. The source has a steep spectrum, i.e. $\alpha_{843\,\mathrm{MHz}}^{1.4\,\mathrm{GHz}} \sim 2$, and its total radio power, $\mathrm{P}_{1.4\,\mathrm{GHz}} \sim 2 \times 10^{23}$ W Hz^{-1}, is the lowest known to date. The radio power of the halo and the X-ray parameters of the cluster, such as L_X and kT, nicely fit the correlations found in the literature for the other halo clusters, extending them to low radio powers. We found that the total number of electrons injected in the cluster environment by the head-tail source is enough to feed the halo, if we assume that the galaxy has been radio active over a large fraction of its crossing time. Given the high statistics, we computed the radio luminosity function for both early and late type galaxies

in this region, finding for elliptical and S0 galaxies consistency with Ledlow & Owen (1999). Given the lack of bright radiosources that we found analysing the whole A3558 complex, this result suggests that the deficit is entirely due to the A3558 cluster. Moreover, a population of faint ($\log P_{1.4\mathrm{GHz}}[\mathrm{W\ Hz^{-1}}] < 22$) radiogalaxies has been found: half of these objects are blue, suggesting that starburst is the driving radio emission mechanism. Finally, we found 14 spiral galaxies, whose ratio between radio and optical emission is similar to that of galaxies located in rich and dynamically evolved clusters.

• It is known that cluster spiral galaxies tend to have less HI with respect to field objects. It has been proposed that the dynamical events acting during a merge could be responsible for the HI depletion. In order to check this hypothesis, we started a project aimed at observing the neutral hydrogen content of spirals in the A3558 complex. As pilot observations, we obtained time at the ATCA telescope for the coverage of three fields with exposure time of 12 hours each in a band corresponding to the velocity interval [10700–18000] km s^{-1}. The data are currently in the reduction phase.

This work is carried out in collaboration with T. Venturi, G. Brunetti (IRA–CNR, Bologna), D. Dallacasa (Astronomy Dept., Univ. of Bologna), R. Morganti (ASTRON, Dwingeloo) and R.W. Hunstead (Sydney Univ.).

• A3528, the dominant cluster of the complex, is a double cluster formed by two twin subclumps separated by 0.9 h^{-1} Mpc, and the other two clusters of the complex (A3530 and A3532) are a close pair, separated by $\sim$ 1 Mpc. Gastaldello, ... Bardelli, ... Zucca (2004) studied A3528 with XMM-*Newton* observations, obtaining surface brightness, temperature and abundance maps (see Fig. 11).

Although a bridge of hot gas connecting the two clumps has been found, no shock is detected: this fact is unexpected, given the estimated masses of the clumps ($\sim 8 \times 10^{13}\ M_\odot$ each) and their relative distance. The most reasonable explanation is that the merging was not head-on but off-axis. After having subtracted a β model from the surface brightness of the two subclumps, we found emission excesses which can be used to determine the infalling direction. The conclusion is that this system is in an off-axis post-merging phase, with the closest core encounter happening $\sim$ 1–2 Gyrs ago. The interesting point is that the optical blue luminosities of the two sub-clumps, which are twins with regard to the X-ray properties, differ by an order of magnitude. This could indicate that one of the two clumps suffered more

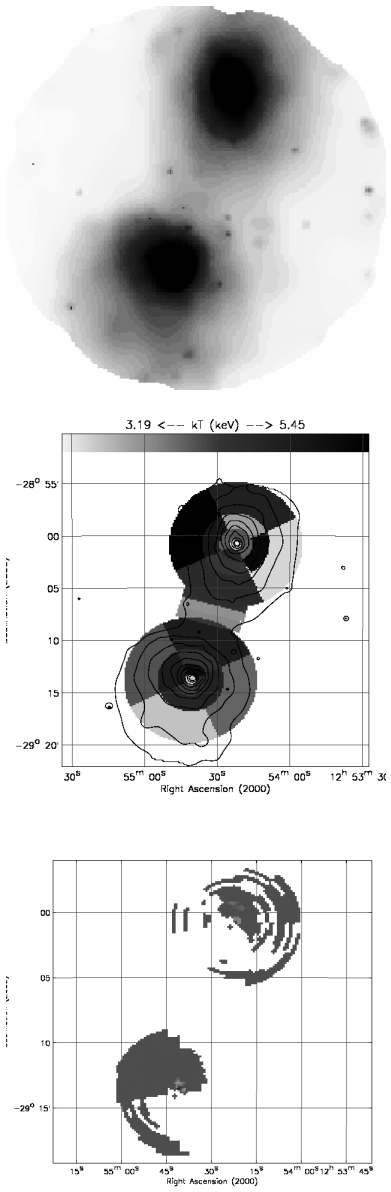


Figure 11: XMM-*Newton* observations of A3528. *Upper panel:* X-ray surface brightness distribution; note the hot bridge connecting the two subclumps. *Middle panel:* temperature map. *Lower panel:* surface brightness residuals, obtained after having subtracted a smoothed distribution.

than the other from the galaxy "peeling" process, probably induced by a larger path through the large-scale environment. XMM-*Newton* data on the couple A3530/A3532 are at present in the reduction phase. Our general conclusion is that, although the two single pairs of clusters (the two clumps of A3528 and A3530/A3532) are mergers in an advanced state, the A3528 complex as a whole is at an earlier moment of collapse with respect to the A3558 complex, and the masses involved here are probably lower.
This work is carried out in collaboration with S. Ettori (ESO), S. DeGrandi (INAF–Milan Obs.), S. Molendi, F. Gastaldello (IASF–CNR, Milan) and T. Venturi (IRA–CNR, Bologna).
Further information about this project can be found on the WEB [6].

S. Bardelli, A. Cappi, F. Marini and E. Zucca, in collaboration with L. Moscardini (Astronomy Dept., University of Bologna), S. De Grandi (INAF–Milano Obs.) and S. Ettori (ESO) are studying the two clusters A2061 and A2067 in the central region of the Corona Borealis supercluster. These two clusters appear to be separated by 1.8 h^{-1} Mpc on the plane of the sky, suggesting the possible presence of interaction. From two BeppoSAX observations (50 ksec each), we estimated the global temperatures, the temperature profiles and maps for A2061 and A2067. We did not find evidence of interaction between these two clusters. However, from an analysis of the bi-dimensional distribution of the hot gas, A2061 turned out to be elongated along the axis connecting its two dominant galaxies. Moreover, in between these two galaxies we found evidence of a significant increase of temperature, due to a shock with a Mach number of 2–3. We speculated that a group of galaxies merged in A2061 and is now near the center of the cluster (Marini, Bardelli, Zucca, ... Cappi et al. 2003). The derived infall velocity is about 2000 km s^{-1}, similar to other cases found in literature.

2.4.2 The MUSIC project

People involved at OAB: Cappi.

A. Cappi is involved in a project (MUSIC, MUltiwavelength Sample of Interacting Clusters) with researchers at the Observatoire de la Côte d'Azur (S. Maurogordato, C. Benoist, A. Bijaoui, E. Slezak),

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

the CEA/CEN in Saclay (M. Arnaud, J–L. Sauvageot), and Innsbruck University (C. Ferrari) aiming at a multiwavelength study of galaxy and gas dynamics in a selected sample of galaxy clusters. The final aim of the project is the realization of a homogeneous database of clusters in different evolutionary phases, suited for a systematic statistical study and a quantitative comparison with theoretical predictions. This project is based on optical observations (mainly at the ESO 3.6m and CFHT telescopes, but presently also at the VLT) and on X-ray observations with XMM-*Newton* and *Chandra*, while complementary radio observations are now carried out in collaboration with Luigina Feretti (IRA–CNR). The first object studied in this survey is A521, a complex, relatively rich cluster at $z \sim 0.25$, in the middle of two filamentary structures, with on-going merging (Maurogordato et al. 2000; Ferrari, ... Cappi et al. 2003). New spectroscopic observations have increased the number of known redshifts, giving a detailed map of the substructure and dynamics of this complex system, which appears to be at least qualitatively consistent with the expectations of hierarchical models of structure formation. Another cluster we have studied in detail is A3921, which appears to be characterized by a bimodal structure, and for which we have obtained deep photometric catalogues and measured more than 230 new redshifts, while XMM-*Newton*/EPIC observations have been obtained by our CEA/CEN collaborators (see Ferrari, ... Cappi et al. 2004). One important aspect of the merging process is the way it may affect star-formation in galaxies, and we have planned more imaging and spectroscopic observations to map the distribution and properties of star-forming galaxies in interacting clusters. In particular, we are at present carrying out observations with VIMOS at the VLT, in order to obtain a large number of high resolution spectra for A2163, a cluster at $z \sim 0.2$. Moreover, a dynamical study is currently carried out also on another, regular cluster, A1413, for which the Sunyaev-Zeldovich effect has also been detected, and A1750. Other clusters will also be observed in the optical, X-ray and radio passbands, to cover the main phases of cluster evolution.

2.4.3 Optically selected galaxy clusters at high redshift

People involved at OAB: Bardelli, Zucca.

A sample of a few hundred galaxy cluster candidates has been extracted from the wide angle multicolor ESO Imaging Survey (EIS),

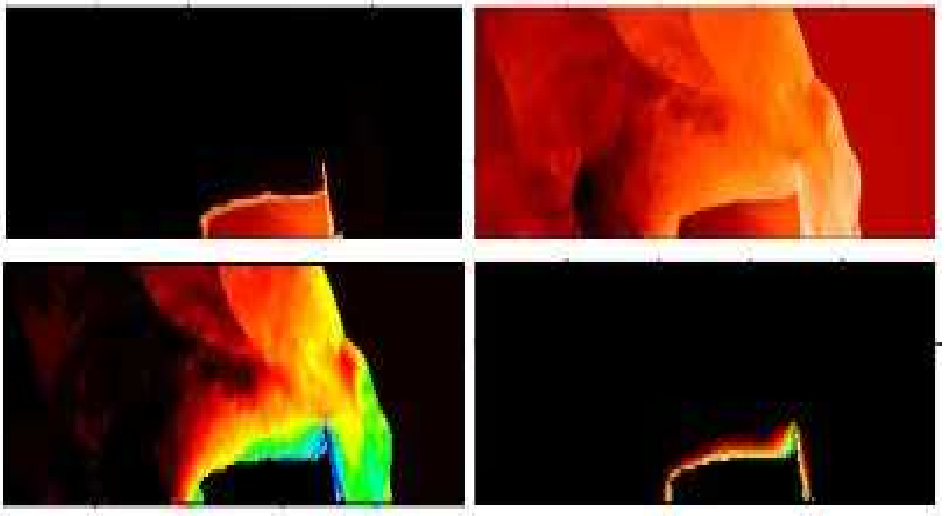
using a matched filter algorithm in the I band. The estimated redshift range of these candidates has a high redshift tail reaching $z \sim 1.3$. This sample will allow to determine the structural parameters and the galaxy population characteristics of clusters of different richness in a wide range of redshifts (Da Costa et al. 2001).
A great effort has been undertaken in order to have a spectroscopic confirmation of a subsample of high redshift EIS clusters. In particular, we confirmed three clusters at $z = 0.81, 1.14, 1.30$ (Benoist et al. 2002; Joergensen, Bardelli, Zucca et al. in prep.). It is particularly important that the two systems at $z > 1$ are the most distant clusters identified so far by their optical properties alone. The cluster at $z = 1.30$ coincides remarkably well with the location of a firm X-ray detection ($> 5\sigma$) in a ~ 80 ksec XMM-*Newton* image (Neumann, ... Bardelli, Zucca et al. 2003). Moreover, we detected in the same image another X-ray emission from a serendipitously found concentration of infrared galaxies at an estimated redshift of $z = 1.7$. The two emissions are consistent with a point-like profile and therefore are likely to be associated with cluster AGN. However, we cannot exclude that the hot gas emission of the clusters is extremely peaked, as expected for proto-clusters.
This work is carried out in collaboration with L. da Costa and S. Arnouts (ESO), C. Benoist (Nice Obs.), L. Olsen and H. Jørgensen (Copenhagen Obs.), A. Biviano and M. Ramella (INAF–Trieste Obs.), M. Scodeggio (IASF–CNR, Milan), D. Neumann and M. Arnaud (CEA/CEN, Saclay).

2.4.4 Properties of optically very luminous galaxies

People involved at OAB: Cappi.

A. Cappi is investigating the nature of galaxy systems hosting optically very luminous galaxies (VLGs, $M_B \leq -21$). This work is carried out in collaboration with C. Benoist, S. Maurogordato (Obs. de la Côte d'Azure) and L.N. da Costa (ESO). In previous work on the Southern Sky Redshift Survey 2 (SSRS2; Benoist et al. 1996; Cappi et al. 1998a,b; Benoist et al. 1999; Cappi et al. 2001) it was shown that the clustering amplitude of galaxies increases for galaxies with $L > L_*$ (with a non-linear bias) and that VLGs have a correlation length approaching that of clusters, even if most of them are not in rich clusters; such results have been confirmed by the 2dFGRS (see e.g. Norberg et

al. 2001). In our recent work (Cappi et al. 2003) we have analysed in more detail the environment of a subsample of our VLGs using partly our own spectroscopic observations obtained at the 1.93m telescope at the OHP, and mainly the data for fainter galaxies obtained from the 2dFGRS, selecting those which are within $1.5h^{-1}$ Mpc from the VLGs. In this way it has been possible to confirm that many faint objects previously detected in the DSS images centered on VLG fields are at the same redshift of the VLG, and that late-type VLGs appear indeed to be in poorer systems, comparable to the Local Group. Present work is focalised in the analysis of the new available databases (the 2dFGRS final release and the SDSS), which will allow us to build a more complete and homogeneous sample of VLGs and to better determine their statistical properties. We have also planned to perform Hα observations of VLG groups with the Wide Field Imager (*WFI*) at the ESO 2.2m telescope, using filters centered on the VLG redshift, in order to efficiently detect fainter candidate members, and to study the star-forming galaxy population and the luminosity function of the system. The aim is to understand the evolutionary properties of this class of poorly known systems. As an example, one important issue is the much debated overabundance of low-mass satellites in the Local Groups with respect to simulations, and we would like to know if this is a common property of other similar groups.



Galactic wind in a starburst galaxy. The figure shows a snapshot of a dense cold cloud overrun by a hot galactic wind. The simulation takes into account radiative losses and heat conduction. The top panels show the gas density (left) and pressure (right). The bottom panels show the X-ray (left) and OVI (right) emissivity. The physical dimension of each panel is 100×30 pc^2. The radius of the initially spherical cloud is 10 pc.

People involved at OAB:

- *Scientific staff:* R. Bedogni, A. D'Ercole, P. Londrillo.

A. D'Ercole, in collaboration with F. Matteucci (Trieste Univ.), S. Recchi (University of Kiel) and M. Tosi continued the studies about the effects of SN explosions in starburst galaxies. The 2D simulations performed in the past (which take into account two different istantaneous bursts) are able to describe the general chemical and dynamical characteristics of the starburst galaxy IZw18. However, an analysis of the stellar population indicates that the first star burst must be continuous over a time span of several hundreds Myr. We thus introduced the possibility of continuous activity in our code. Under a number of simplyfing assumptions (centrally concentrated star formation and constant chemical composition of the newly formed stars) it was possible to study the dynamical and chemical effects of two star bursts extended in time and separated by a quiescent period, adopting the parameters suggested by Aloisi, Tosi & Greggio (1999). Contrary to models with instantaneous bursts, the present models are more stable and match the observed abundance ratio over longer time spans.

In collaboration with A. Marcolini and F. Brighenti (University of Bologna), D'Ercole extended to 3D a previously developed 2D hydrocode and studied the effect of the ram pressure of the IGM on dwarf galaxies and on galactic winds generated by starbursts occurring in these galaxies. A number of models have been run, covering different values of galactic mass, IGM ram pressure and inclination angle between the galactic rotation axis and the galactic velocity. While galactic winds in galaxies at rest carry away almost all the freshly produced metals, for particular combinations of the parameters the ram pressure may increase the fraction of metals which remain trapped into the ISM.

Finally, in collaboration with A. Marcolini and D. Strickland (Johns Hopkins University, Baltimore) D'Ercole started 2D simulations of cold clouds overrun by a hot galactic wind taking into account the heat conduction. The aim of these simulations is to explain the spatial distribution of the X-ray and OVI emissivity observed in starburst galaxies.

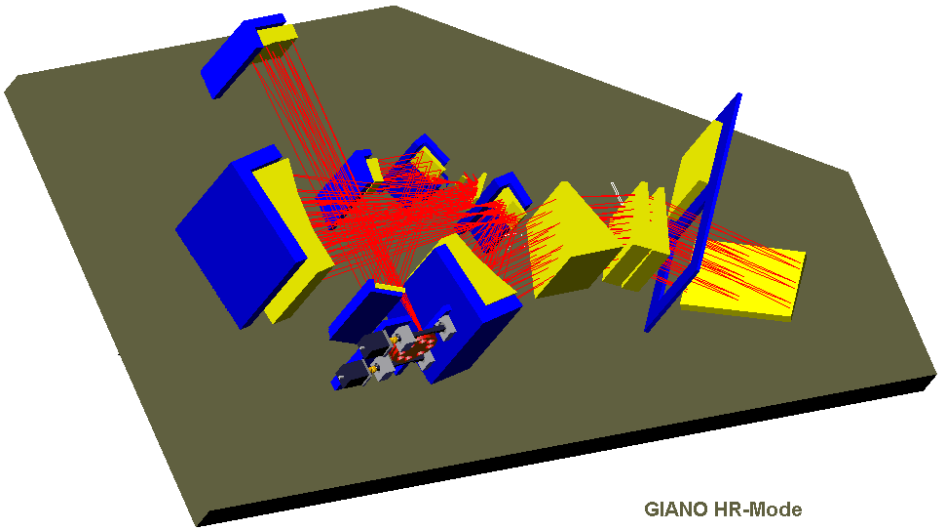
R. Bedogni has computed numerical simulations of SN remnant evolution in a cloudy medium for both Type I and Type II Supernovae. Particular attention has been paid to the evolution of the

Rayleigh-Taylor instabilities inside the remnants because of the effects of cooling. More detailed simulations are done for the shock-clouds interactions for a wide range of the density contrast between the cloud and the ambient medium.

R. Bedogni, in collaboration with A. Di Fazio, (INAF–Rome Obs.), introduced the effects of a variable drag, in function of the Mach and Reynold numbers, in a more general program to obtain the dynamical evolution of a self-gravitating protocloud with turbulence. The fragmentation of a protocloud has been described using a "semi-empirical" model of turbulence.

P. Londrillo has devised a new general method (Upwind Constrained Transport, UCT) to design higher order Godunov-type schemes for magneto-hydrodynamics (in collaboration with L. Del Zanna).

P. Londrillo, in collaboration with L. Ciotti (Astr. Dept., University of Bologna) and G. Bertin (University of Milano), has performed numerical and analytical analyses of a class of toroidal equilibria having relevance for stellar systems. Preliminary results have been presented at the AICPS Conference (Como, 2003).


GIANO HR-Mode

3D view of the GIANO spectrograph: the optical bench with optics and ray-tracing.

People involved at OAB:

- *Scientific staff:* C. Cacciari, E. Diolaiti, R. Merighi, L. Origlia, V. Zitelli
- *Technical staff:* G. Bregoli, G. Innocenti, P. Montegriffo
- *Contracts:* M. Lombini, E. Rossetti

4.1 The FLAMES project

People involved at OAB: Cacciari, Merighi, Rossetti

The Bologna Observatory is a member of the Ital-FLAMES Consortium, which also includes the Observatories of Trieste, Cagliari and Palermo, that participated in the completion of the FLAMES project. FLAMES is an instrument facility for multi-object spectroscopy developed at ESO. It consists of several components: a Nasmyth corrector, a fiber positioner, a fiber link to the UVES high resolution spectrograph, an intermediate resolution optical spectrograph (GIRAFFE) with its own fibre system, and coordinating observing software.

As part of the Ital-FLAMES Consortium, the Bologna Observatory has provided the Templates for FLAMES in all observing modes. This activity has been carried out by the contractor E. Rossetti, with assistance from Ferraro (Astron. Dept., Bologna Univ.) and Merighi, in collaboration with personnel at ESO and the Trieste Observatory, and with the coordination of Cacciari, P.I. of the Ital-FLAMES Consortium.

The FLAMES facility is now completed and operational. It was offered to the community with the ESO Call for Proposals of September 2002, and routine observations started on April 1st 2003. Observations for Science Verification (SV) were successfully performed during the period Jan 24–Feb 2, 2003. The Bologna Observatory participated in SV with observations of red giant stars in the globular cluster NGC 2808 aimed at detecting mass outflows from the atmospheres of these stars (Cacciari et al. 2003). The same observations were used to derive Na and O abundances (Carretta et al. 2003, 2004).

4.2 The L3CCD project

People involved at OAB: Bregoli, Ciattaglia, Innocenti

Since the year 2001 a joint collaboration between Bologna and Arcetri was started, in order to provide high resolution optical images based on a fast detector and suitable dedicated software, for use in systematic programs at the Loiano telescope, and later to develop a photon counting wavefront sensor for adaptive optics on large optical telescopes.

In the framework of this project, a program of laboratory- and later sky-tests of this kind of detector for adaptive optics applications was started in the spring of 2002, involving the Arcetry Observatory, the Astronomy Dept. of the University of Bologna and the Bologna Observatory. As a first step we have interfaced a commercial photon-counting controller to a new type of detector: the L3CCD, an avalanche intensified CCD from E2V (ex Marconi AT) with the aim of developing a low-noise wavefront detector for adaptive optics. The system performed as an efficient and almost ready-to-use speckle camera with a duty cicle of 20 msec. During the year 2003 the first electronic generation was developed, as well as a suitable cryogenic system for the sensor.

All of the optical bench data acquisition and analysis software have been developed at the Bologna Observatory. This suitable software requires a careful synchronisation among several instruments and great acquisition flexibility to fulfill the specific requirements of fast pixels. In this way the great flexibility of the characterization facility allows to characterize sensor parameters easily, quickly and accurately, even in a very low light regime. Many custom parts for both the electronic controller (housings) and the cryogenic system have been developed at the OAB, as well as the optical bench and the speckle camera.

4.3 GIANO: An ultra-stable IR spectrometer optimized both for low and high resolution

People involved at OAB: L. Origlia, M. Rossetti, P. Montegriffo, M. Lolli

The recent development of high sensitivity infrared (IR) spectrometers has opened a new window in astrophysics. The investigation of

the 1 to 2.5 μm band has yielded the discovery of a wealth of diagnostic tools, both in terms of absorption features and emission lines, which are crucial for a thorough understanding of several hot topics of modern astrophysics, from faint solar system objects and extrasolar planets to stellar clusters and galaxies, up to the highest redshift quasars.

The much reduced extinction at these wavelengths allows IR spectrometers to pierce the dust embedding several Galactic and extragalactic objects, which are heavily obscured in the optical. At high redshift several emission and absorption spectral features, commonly exploited when studying local galaxies, are shifted into the IR. These and several other advantages of IR spectroscopy have led to a rapid growth of the community of astronomers, from essentially any scientific field, making use of these facilities.

GIANO is an optimized near IR spectrograph which can yield, in one shot, complete 0.9–2.5 μm spectra either at low (RS = 500) or high (up to R = 50,000 with a 0.5" slit) resolutions maintaining, in both modes, a very high stability and throughput throughout the whole spectral range.

This project is part of the Second Generation Instrumentation Plan of the Telescopio Nazionale Galileo (TNG) located at Roque de Los Muchachos Observatory (ORM), La Palma, Spain.

The core of GIANO is the spectrometer unit which uses, in double pass, the same optical elements (3 aspheric mirrors) as collimator and camera. These feed, through cross-disperser prisms, a commercial 23.2 ll/mm R2 echelle grating acting as high resolution disperser. All these elements and the 2048^2 Hawaii-2 array are fixed to an optical bench which will operate in vacuum at cryogenic and thermostated temperatures.

By simply inserting a flat mirror in front of the echelle the instrument "changes its face" (hence the name GIANO) and becomes a low resolution spectrometer with an unprecedented combination of spectral coverage, throughput and resolution. Measurements of circular and linear polarization can be obtained using a combination of beam splitters and super-achromatic retarders which can be inserted/rotated in the pre-slit optical system.

More details about the project can be find on the GIANO Web page (http://www.bo.astro.it/giano).

4.4 Large Binocular Camera

People involved at OAB: Diolaiti

The Large Binocular Camera (LBC) is a double imaging camera for the Large Binocular Telescope (LBT). The project involves the Astronomical Observatories of Roma, Arcetri, Padova and Trieste. Each LBC unit includes a 6-lens optical corrector and a 6K $\times$ 6K CCD detector array; the two cameras, also named Blue and Red Channels, are optimized for the blue and the red parts of the visible spectrum and are characterized by a very fast focal ratio (F/1.45) and a wide field of view (approximately $30'$ in diameter). This instrument has been designed for multi-band observations in seeing-limited mode; it is provided with two types of filters: standard photometric Bessel filters (U, B, V on the Blue Channel and V, R, I on the Red Channel) and custom filters, still under definition, designed for specific applications. The Blue Channel of LBC will be the first light instrument of the Large Binocular Telescope.

Emiliano Diolaiti, formerly with the University of Padova and the Osservatorio Astrofisico di Arcetri, has been hired by OAB in December 2003. He collaborates with the Arcetri group on the design and integration of the opto-mechanical parts of the instrument. In particular, during the year 2003, he has worked on the finalization of the Red Channel design, on the laboratory integration and alignment of the Blue Channel corrector, which is going to be installed at the telescope in 2004, and on the definition and procurement of the filters, still in progress.

4.5 MAD

People involved at OAB: Diolaiti, Lombini

MAD is the acronym of Multi–Conjugate Adaptive Optics Demonstrator. It is an adaptive optics prototype to be installed on a VLT Unit Telescope, designed and built in the framework of a collaboration among ESO, two INAF Observatories (Arcetri and Padova) and the Faculdade de Ciencias de Universidade de Lisboa (Portugal). The main purpose of this prototype is the demonstration of the multi-conjugate adaptive optics technique, which has been proposed to overcome the anisoplanatic effects typical of the single-conjugate

adaptive optics. This goal is realized by means of several deformable mirrors (two in the case of MAD), conjugated to different altitudes and driven by a control system which collects the information on the atmospheric turbulence using several reference stars, in order to reconstruct a kind of three-dimensional mapping of the turbulence. Two different wavefront sensing techniques are implemented in MAD, namely star-oriented and layer-oriented. A very interesting feature of the latter approach is the possibility to combine optically the light of even very faint stars, thus improving the sky coverage with natural guide stars only. The $2'$ field of view corrected by MAD is imaged onto a cryogenic infrared camera.

The INAF partners are in charge of the design and construction of the layer-oriented wavefront sensor. In particular, concerning the people involved at OAB, Emiliano Diolaiti has worked mainly on the optical design, on the procurement of the optical components and on the system performance analysis; Matteo Lombini on the laboratory integration and on the study of the science cases, with particular emphasis on deep field surveys of extra-galactic objects.

4.6 LINC–NIRVANA

People involved at OAB: Diolaiti

The LINC–NIRVANA project involves the Osservatorio Astrofisico di Arcetri and three German institutes: Max-Planck Institut für Astronomie (Heidelberg), Universität zu Köln, Max-Planck Institut für Radioastronomie (Bonn). LINC–NIRVANA is a near-infrared imaging interferometer for the Large Binocular Telescope (LBT), designed to achieve the maximum angular resolution possible with LBT, corresponding to its longest baseline. The beams collected by the two telescope units are first corrected by two adaptive optics systems, then cophased by a fast mirror and combined inside a cryogenic near-infrared camera, forming a focal plane interference pattern. The two adaptive optics systems are based on the layer-oriented multi-conjugate approach. Each of them includes two units: a wavefront sensor conjugated to the ground layer, driving the adaptive secondary mirror of LBT, and a mid-high layer wavefront sensor, which may be conjugated to any other layer up to an altitude of 15 km and may drive up to two deformable mirrors.

The INAF partners are mainly in charge of the design and con-

struction of the wavefront sensing units. Emiliano Diolaiti collaborates with the Arcetri group on this task; during the year 2003 he has realized the preliminary optical design of the wavefront sensors and he has contributed to the definition of the mechanical design; moreover he has collaborated with the Heidelberg group on the verification of the cryogenic camera optics design. The instrument has passed a preliminary review. The design phase is still in progress and will be completed before the final review, presumably in late 2004.

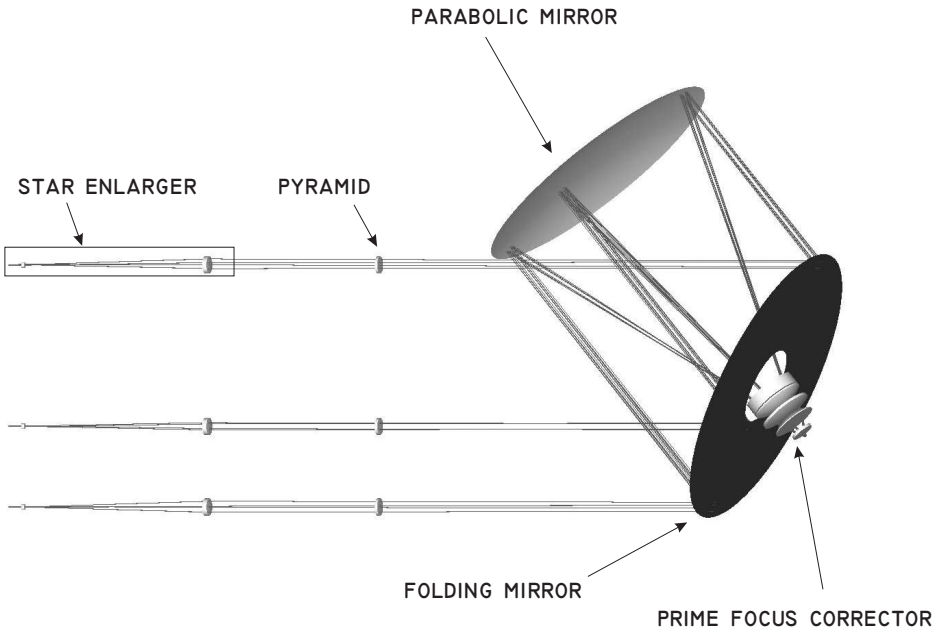


Figure 12: Optical layout of the LINC–NIRVANA ground-layer wavefront sensor.

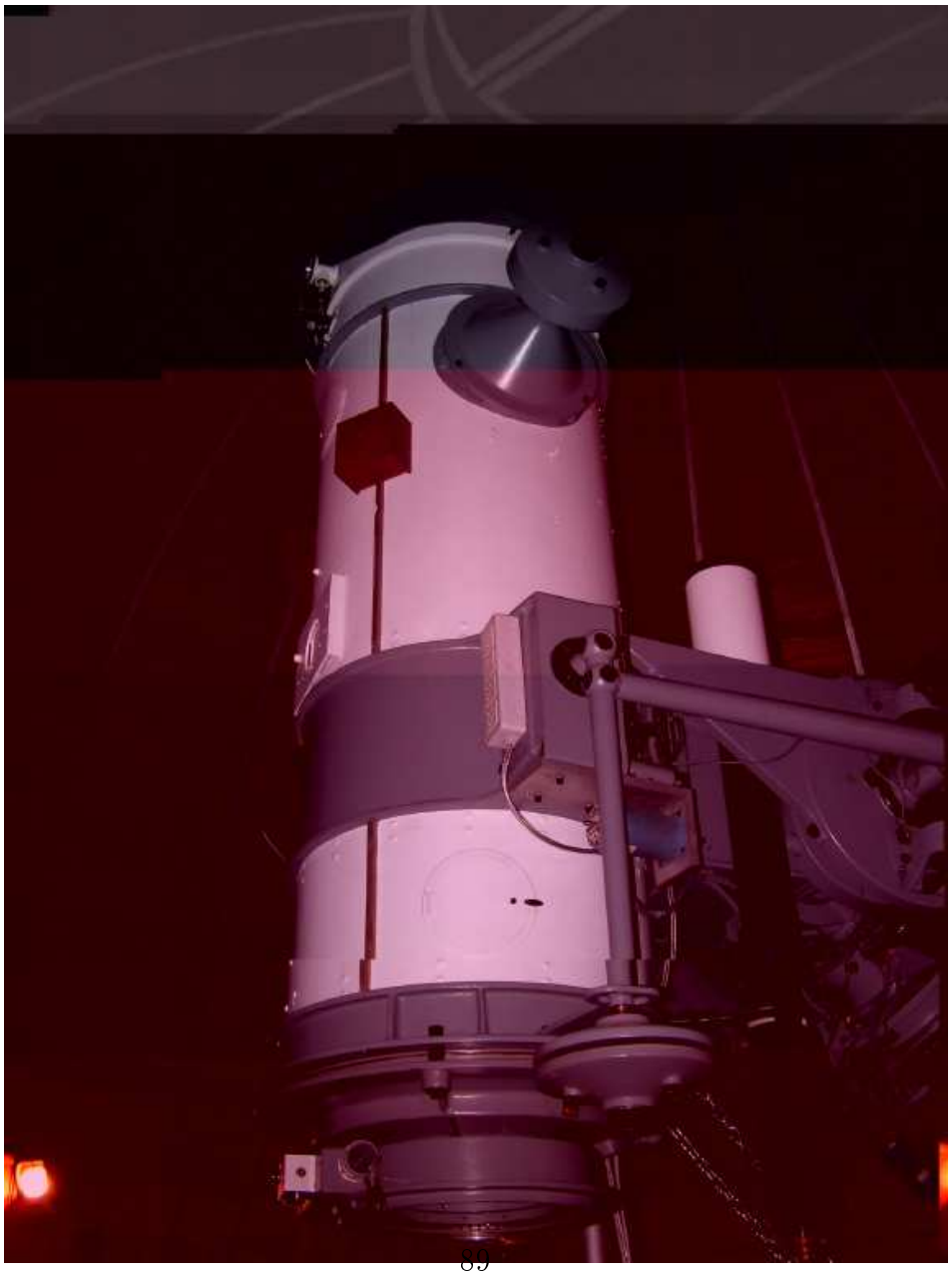
4.7 TNG

People involved people at OAB: Zitelli.

Zitelli is a member of the "Site testing" working group for the Telescopio Nazionale Galileo (TNG).

Since the Canary Islands are under influence of Ocean weather with dominant trade wind from the north, especially during summer time, TNG is influenced by the calima effect: the dust from the Sahara desert. Zitelli with Porceddu (INAF–Cagliari Obs.) and TNG personnel have collected and analyzed dust data from a statistical point of view. The aim of this experiment is to compare the behaviour of dust grains of different sizes and the meteo parameters, to check the influence on astronomical seeing.

5 Loiano observing site



View of the 60cm telescope of the Loiano observing site

People involved at OAB:

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

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

The **152cm telescope**, dedicated to G.D. Cassini, was built by REOSC and has been operating since 1976. A general description of the 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, equipped with a CCD camera EEV 1340×1300 and the possibility to choose between two sets of filters: a standard Johnson-Kron-Cousins system and a Gunn system. An Hα filter has been recently made available too.
2. A *classical*, cooled, five-colour Photoelectric Photometer
3. A two-channel photoelectric Photometer (3 colours).

BFOSC has been the most scheduled instrument, with about 80% of the total allocated time, well matching the seeing and the variable meteo conditions of the Loiano site.

The **60cm telescope** was built in 1933 by Zeiss of Jena following the most modern techniques of the time. It was originally equipped with a photographic camera at the F/3 direct focus and was later modified to a f/20 Cassegrain system. At present it is equipped with a 5-colour photometer, and a new camera, a CCD Marconi (series 4710, 13/μm pixel size, 1055×1026 pxs), is mounted at the Cassegrain focus

modified with a focal reducer to a f/5.6. It is now permanently used by undergraduate students. A techical report can be found on the web page:
www.bo.astro.it/ loiano/ManualeCCD60cm/ManualeCCD60cm.htm.

In summer the 60cm telescope is also used for outreach activities (see section Outreach and educational activities for more detailed information).

Table 1. Cassini telescope

Mount type	English
Optical configuration	Ritchey-Chrétien
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 the 152cm telescope

People involved at OAB: Zitelli, Bernabei, De Blasi, Gualandi, Bruni, Muzi, Salomoni, Bregoli, Ciattaglia, Innocenti.

The 152cm telescope is regularly used for scientific observations, and is available for about 350 nights/year. In the last few years both the 60cm and 152cm Loiano telescopes are also open to students. The statistics of the last years is given in Table 2. Time is allocated every 6 months, starting in January and July. Each program is scheduled tipically for one week, to avoid excessive fragmentation of the observing time.

It is possible to pre-reduce the observed data with a PC in a local network. See section 6.4 for an updated situation of the Loiano computer facilities. MIDAS and IRAF packages are available and it is possible to implement other software facilities.

Table 2. Cassini Telescope – Nights used per year

nights/year	1996	1997	1998	1999	2000	2001	2002	2003
used (t>50%)	106	122	105	98	110	121	133	138
used (t<50%)	26	19	41	22	38	35	31	35
used for test	37	32	58	33	15	10	6	3
not used (weather)	183	180	142	179	189	163	172	107
not used (technical)	3	1	10	4	1	3	0	0
not assigned	11	11	10	29	13	33	23	30

5.2 Applications to the 152cm Telescope

The main observing programs of 2003 at the 152cm telescope are described in the following. For the first time, two long term programs were approved, and were allocated about 20 nights each semester (the first two of the list). Service observing for ToO and monitoring programs is also performed.

1. Focardi P. (Univ. Bo), **Zitelli V.**, Kelm B., Marinoni S.: *The role of environment-activity relationship on galaxies*

2. **Clementini G**. (OAB), Ripepi V., Marconi M.: *The star formation history of Ursa Minor dwarf from its variable stars*

3. Terranegra L. (OACapodimonte), Chavarria C., Moreno M.A. (UNAM, Mexico): *Spectroscopic study of the PMS group near DL Ori*

4. Polcaro V.F. (CNR/IASF): *Peculiar object in young open clusters*

5. Masetti N. (CNR/IASF), Foschini L., Palazzi E., Cappi M., Dadina M., Bassani L., Malaguti G. *Hunting the nature of ultraluminous X-ray source NGC4168-X1*

6. Trevese D. (Univ. Roma La Sapienza), **Zitelli V., Stirpe G.**, Vagnetti F.: *The mass of intermediate redshift QSOs*

7. Masetti N. (CNR/IASF), Palazzi E., Pian E.: *SN2002ap in its nebular phase*

8. Polcaro V.F. (CNR/IASF): *Photometry and Spectroscopy of high mass stars in young open clusters*

9. Nesci R. (Univ. La Sapienza, Roma) and Massaro E.: *Follow up of candidates radio quiet BL Lacs*

10. Pizzichini G., Guarnieri A., Bartolini C., Piccioni A., Masetti N.: *ToO di GRB in particolare rivelati da HETE*

11. Silvotti R. and several CoI: *Pulsating subdwarf B stars: multisite campaign*

12. Giovannelli F. (IAS-CNR) et al.: *Spectrophotometric and photometric observations of X-ray binaries and Interactions with SNRs*

13. Gavazzi G. (Univ. Bicocca Mi), Cortese L. : *Redshift measurements in A1367*

14. Masetti N. (CNR/IASF) et al.: *Search for the optical counterpart of the X-ray source SAX J1532.4+7349*

15. Stassun K. (Wisconsin), Van den Berg M., Tagliaferri G.: *Chandra Orion Megasecond Project Ground Support – flare monitoring*

16. Formiggini L. (The Wise Obs., Israel): *Spectroscopical confirmation of white dwarf and subdwarf candidates from FAUST UV photometry*

17. Ripepi V. (OA Capodimonte): *A multisite campaign for Delta Scuti PMS V346 Ori and HD35929*

18. De Martino D. (OAC): *Fast time photometry of new intermediate polar candidates*

19. Marconi M.(OAC): *Photometric monitoring of Delta Scuti candidates*

20. Foppiani I.(Univ. BO): *Test Marconi L3CCD*

21. Marchesini D. (SISSA/ISAS): *What causes the FRI-FRII dichotomy in radio galaxies*

22. Butler R. (NUI Galway Ir): *A photometric search for binary and variable stars in selected open clusters*

23. Goolden A. (NUI Galway Ir): *Long term photometric monitoring of brown dwarfs*

24. Galleti S. (Univ. Bo), **Federici L., Bellazzini M., Fusi Pecci F.**: *Globular clusters in M31*

- List of applications for undergradate courses of both Italian and European degrees in Astrophysics:

    1. Redfern M. (NUI-Galway-IE): 8 nights (20 students)[7]
    2. Righini (Firenze Univ.): 6 nights (15 students)
    3. Stanga R. (Pisa Univ.): 2 nights (10 students)
    4. Gavazzi G. (Milano Bicocca): 10 nights (8 students)
    5. Trevese D. (Roma La Sapienza): 3 nights (4 students)

5.3 Scientific production involving the 152cm Telescope

1. Mukadam A.S. et al., *Constraining the evolution of ZZ Ceti*, 2003, ApJ, 594, 961.

2. Cortese L., Gavazzi G., Iglesias-Paramo J., Boselli A., Carrasco L., *Optical spectroscopy of galaxies in the nearby Abell1367, Coma and Virgo clusters*, 2003, A&A, 401, 471.

3. Gavazzi G., Cortese L., Boselli A., Iglesias-Pramo J., Vilchez, J., Carrasco L., *Capturing a star formation burst in galaxies infalling onto the Abell cluster 1367*, 2003, ApJ, 597, 210.

4. Gavazzi G., Zaccardo A., Sanvito G., Bonfanti C., Boselli A., *Spectro-photometry of galaxies in the Virgo cluster. II: The data*, 2003, A&A, 417, 499.

[7] *www.physics.nuigalway.ie/Courses/loiano.html*

5. Cortese L., Gavazzi G., Boselli A., Iglesias-Pramo J., *An extra-galactic HII region in the Virgo cluster*, 2004, A&A, 416, 119.

6. Pinheiro F.J.G., D.F.M. Folha, M. Marconi, V. Ripepi, F. Palla, M. J. P. F. G. Monteiro, *Oscillations in the PMS delta Scuti star V346 Ori*, 2003, A&A, 399, 271

7. Ripepi V., M. Marconi, **S. Bernabei**, F. Palla, F. J. G. Pinheiro, D. F. M. Folha, L. Terranegra, A. Arellano Ferro, X.J. Jiang, J.M. Alcalà, T.D. Oswalt, *Multisite observations of the PMS δ Scuti star V351 Ori*, 2003, A&A, 408, 1047

8. Ripepi V., *Recent Observations of PMS delta Scuti Stars*, 2003, Ap&SS, 284, 69

9. Polcaro V.F, **Gualandi R.**, Norci L., Rossi C., Viotti R.F., *The LBV nature of Romano's star (GR290) in M33* 2003, A&A, 411, 193.

10. Schuh S.L., Heber U., Dreizler S., ... , Silvotti R. et al., 2003, Baltic Astronomy, 12, 55

11. Mukadam A.S., ... ,**Bernabei S.** et al., 2003, Baltic Astronomy 12, 71

12. Masetti N., Foschini L., Ho L.C., Dadina M., Di Cocco G., Malaguti G., Palazzi E., *Yet another galaxy identification for an ultraluminous X-ray source* 2003, A&A 406, L27

13. Grandi P., Foschini L., Masetti N., Palazzi E., *1WGA J2223.7-0206; A narrow Line Quasi Stellar Object in the XMM Newton field of view of 3C445*, 2004, A&A, 418, 907

14. Silvotti R., 2003, Proc. of the 2nd Eddington Workshop on Stellar Structure and Habitable Planet Finding, ESA-SP Conf. Proc., eds. F. Favata & S. Agrain, in press.

15. Silvotti R., Bonanno A., Frasca A., et al., 2003, Astrophysics and Space Science (special edition), Kluwer Academic Publishers, in press.

16. de Martino, 2003, NATO Sci. Ser. 105, 321.

17. Piccioni A. et al. (2003): GRB 030324 GCN 1963

18. Guarnieri A. et al. (2003): GRB 030226 GCN 1892

19. Pizzichini G., Ferrero P., Bartolini C., Guarnieri A., Piccioni A., Righini A., **Bruni I.**, *HETE GRB 030329, correction to Rc observations in Loiano*, 2003 GCN 2228

20. Bartolini C. et al. (2003): GRB 030329 GCN 2003

21. Guarnieri A. et al. 2003: GCN 1940

22. Bartolini C. et al. 2003: GRB030329 GCN 2030

23. Guarnieri A. et al. 2003: GRB30217 GCN 1873

24. Carpino M., Righini A., **Gualandi R.**, Forti G., *Minor Planet Observations [598 Loiano]*, 2003, MPC 49907 1C

25. Santangelo MMM, Ciabattari F., *Comet observations [598 Loiano]*, 2003, MPC 49222 50S

26. Masetti N., Foschini L., *Optical observations of the IGR J18539+0727 field*, 2003, ATel. 158, 1

27. Pizzichini G., Ferrero P., Bartolini C., Guarnieri A., Piccioni A., Righini A., **Bruni I.**, *GRB030329: rc photometry in Loiano*, 2003, GCN 2136

28. Masetti N., Foschini L., Ho L.C., Dadina M., Di Cocco G., Malaguti G., Palazzi E., *The Challenge of identifying Optical Counterpart to ultraluminous X-ray source*, 2003, MSAIS 3 256 406 L27

6 Computer center and computer network

People involved at OAB:

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

The principal activity of the computer center during 2003 has been addressed to the improvement of the network security and network connections. Old computers have been replaced with newer ones or new hardware has been added. A new linux server, providing DHCP and CUPS printing services, has been installed. A Gbit lan connecting the 152 cm Loiano Observatory with the old 60 cm telescope and the guesthouse has been implemented.

6.1 Computer center improvements

People involved at OAB: Delpino, Di Luca, Gatti, Lolli, Madama, Merighi, Montegriffo, Nardinocchi, Policastro.

During 2003 several old Alpha workstations were replaced by newer ones or with PCs running Linux OS. Several high performance PCs, equipped with AMD Athlon XP 2200+ and 1GBy RAM have been installed, working typically as personal computer facility for large data reduction programs. To this purpose, these machines were also equipped with DAT and DVD-RW units, for data backup. The hydrodynamics group has completed the alpha workstation cluster adding a new HP DS20 Server with 1GByte RAM and 34GB disk.

The number of PCs used as Unix-Linux workstations continued to increase during 2003. Most of them have been updated with DVD-RW and SCSI DAT tapes.

A new HP Proliant DL380 Xeon bi-processor power-redundant linux server has been installed. This computer works as secondary DNS for the bo.astro.it domain, acts as DHCP server for the site and as CUPS printing server. The DHCP service is available only for authorized (via mac address) computers. This server now also hosts the network license manager for the IDL package and a new local news server (INN).

After the Observatory outsourced the mail service to the CeSIA (Centro per lo Sviluppo e Gestione Servizi Informatici d'Ateneo – Univ. of Bologna), two Active Directory servers, providing LDAP service for the mail server, have been installed.

In order to improve the network security, a firewall Fortigate 400 has been installed. This device has several advanced functions. Besides filtering incoming traffic and allowing the creation of network areas with different security policies, it also applies anti-virus filtering on incoming packets, black-listing of http sites and mail control on both input and output messages.

Additional personal firewalls have been installed on several PCs, both Linux and Windows.

6.2 Improvements in the geographic network

6.2.1 Computer networks

People involved at OAB: Delpino, Di Luca.

During the past years work has been done concerning all the relevant aspects of computers networks both at local (LAN) and geographical (MAN and WAN) level with the aim of testing the new generation protocols at OSI levels 2 and 3 (pure ATM, ATM LAN emulation, IP next generaion, OSPF). ATM in particular has been tested extensively due to the possibility of realizing multiple high speed connections on the same links, with static or dynamic band partition. 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).

Delpino has drawn the development model for the project of the new broad-band research network of the Emilia Romagna region, which is based on an private backbone at 1000 Mbit/sec. On that model basis a hierarchical structure, formed by a top level independent backbone interfacing a large number of campus networks, has been planned.

6.2.2 Web applications

People involved at OAB: Gatti.

Gatti has developed the Administration's web site, where several functions are available. Among them: staff database, different sets of forms for internal use, legislative references and other useful information.

6.3 Improvements in the accessory services

People involved at OAB: Di Luca, Merighi.

Concerning accessory service improvements, a new high-quality network printer HP 4300N (17 ppm, 600dpi, auto-duplex unit) and a new color laser printer OKI C 7300 have been bought. This new color laser printer has advanced capability for both speed and protocol support.

6.4 Loiano station

People involved at OAB: Lolli, Gualandi, Diluca

After the installation in 2002 of the 2Mbit connection between the Loiano Observatory and Bologna, a fiber optic link connecting the 152cm Loiano telescope and the old 60cm telescope and the guesthouse has been installed. This link allows also the connection of a GPS receiver belonging to the Department of Physics of the Bologna University with downtown computers. This equipment is part of a geo-physics local network monitoring earth-crust movements.

6.5 Routine activities

People involved at OAB: Di Luca, Gatti, Lolli, Madama, Montegriffo, Policastro.

Besides all the activities described above, a large part of the work of the computer center staff has been, as usual, devoted to routine activities such as hardware and software maintenance, failure management and user assistance.

Routine operations include:

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

6.6 Other activities

People involved at OAB: de Ruiter, Gatti, Montegriffo.

Other computing activities have been carried out during 2003. Among them:

In 2002 and 2003 a project financed by the European Union in the framework of the "Information Society and Technologies (IST)" programme was carried out by de Ruiter as a collaboration between the OAB, IRA and CINECA (all at Bologna), the IFCTR (Milano), the Observatory of Catania, and ASTRON (the Netherlands). The aim of this project was to produce a software package for displaying and manipulating three dimensional data sets. The data sets may be 3D images (i.e. gridded data), or lists of data with three or more variables. The package can handle a wide variety of data formats (including FITS files). The project was successfully completed at the end of 2003. A User Guide is available on-line; a paper version is in press.

Gatti continues the collaboration with the Administration of the Observatory providing the informatic support, nowaday essential to the administrative work, and writing specific programs and procedures.

Montegriffo has developed original software for data analysis in digital photometry in crowded fields.

- CATAPACK is a package for management and manipulation of photometric catalogues of stellar fields, particularly suitable for the determination of accurate astrometric solutions: it has been conceived for the preparation and execution of some Observatory scientific programs such as that of the ItalFLAMES Consortium. This package has been designed to be user-friendly and portable on different platforms (Compaq TrueUnix64, Linux, HP, Sun). Written in the ANSI C language, it is provided with autoconfiguration tools based on GNU automake, autoconf and libtool. The core of the package is represented by two programs: CataXcorr e CataComb.

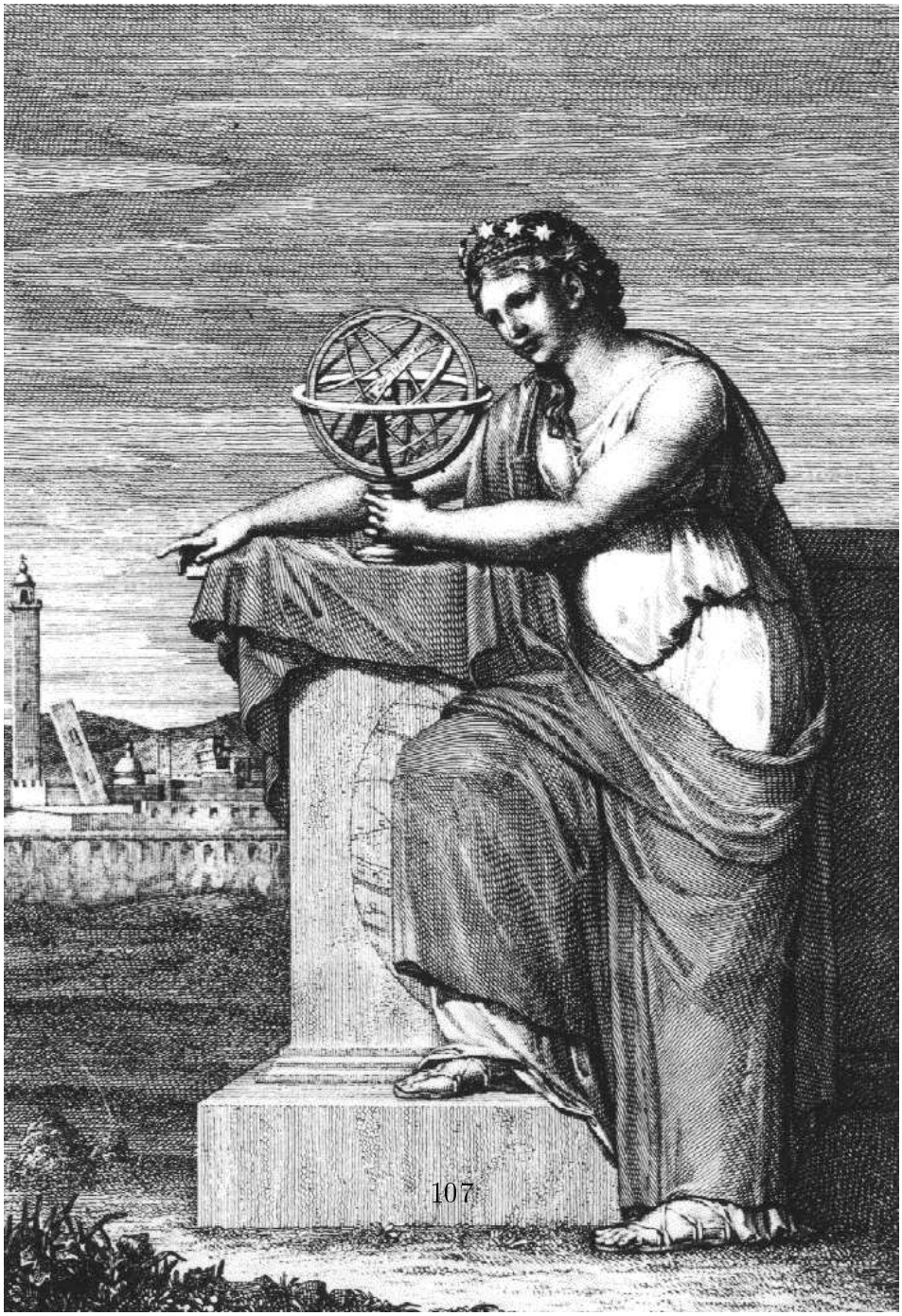
- CataXcorr (Catalogues Cross Correlator) performs cross correlations and coordinate transformations between an arbitrary number of input catalogues. The program is able to find accurate transformations with a common reference system of linear or spherical coordinates, independently of scale differences, axis rotation or inversion, producing astrometric solutions and relative calibrations. The main characteristic is its high degree of automatization thanks to a pattern recognition algorithm based on identifications of similar triangles. The program has a GUI based on the Gnu GTK library that permits complete user control over the algorithms and an immediate check of results. Spherical coordinate projections are realized through Mark Calabretta's WCSLIB libraries; coordinate models conform to recent FITS standards and by a simple auxiliary script it is possible to put all relevant WCS information in the original fits images from which catalogs have been produced.

- CataComb (Catalogues Combiner) is a program that allows to combine an arbitrary number of input catalogs producing a single output catalog with the desired quantities. Objects from

input catalogs can be associated by means of a cross-correlation table produced by CataXcorr or by identification number. CataComb's main characteristic is flexibility: free format for input catalogs, high number of files that can be processed simultaneously (up to 64), output content controlled by a very simple and intuitive syntax thanks to a parser able to interpret arithmetic and logical expressions of high complexity.

CataPack is currently used and tested by many astronomers at various INAF Institutes (e.g. OAB, TNG and Rome Observatory). OAB, as a member of the ItalFLAMES Consortium, was involved in the "Science Verification" stage of the instrument: the requested accuracy for observation targets was of 0.2 arcsec only. Astrometry derived with CataXcorr in severely crowded star fields has been successfully tested during the 1st GTO phase (May 2003) when all given targets (~ 250 stars in M22; ~ 800 stars in Omega Cen and 130 stars in NGC2808) were correctly observed. GUI for CataComb is under development: it can produce fast plots of diagrams and maps, mean ridge lines and bestfit relations and also density maps (Hess diagrams and density contour plot).

7 Library



People involved at OAB:

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

A special task for 2003 was the intense contribution to the first complete INAF report on its libraries, which was prepared for INAF between November 2002 and May 2003. On the whole, our library's activity for 2003 has in any case seen a main emphasis on the ordinary activities, which remain well-appreciated by our > 950 registered users.

It is widely accepted that the mission of modern libraries focuses on the access services to information. At this time, we have again managed as many as $\sim$80 document delivery requests for a total of 90 articles; our library is mainly a supplier (with $\sim 75\%$ of requests being sent out to other libraries and 25% asked for internal researchers), which demonstrates that the internal research personnel has generally been satisfied with the documentation our library has given access to in 2003.

The number of inter-library loan requests has increased by 30%, with an average of almost one a month. Here too, only $\sim$ 8% of requests comes from the inside, whereas the large majority of requests managed has served external libraries and researchers. Our library's web page in 2003 has been visited as many times as during the first year of its complete renovation: last year's visits have exceeded 9000, making it one of the best-liked web resources on the local server. The cataloguing activities have continued, acquiring to the online catalogue older books previously catalogued only in paper form, as well as local dissertations. Thus, about 500 records have been made available in the online mode. New acquisitions mainly means new books, purchased by the OAB for local researchers for an amount of $\sim$5000 euros in 2003. Librarians still also take care of the many daily book loans, train part-time students, update the national and the local online catalogues, update the inventory database for books and journals, assist local students and the public in general with their documentation needs, supervise journal and book suppliers, manage journal binding.

In the staff, Pietro Candelaresi and Marina Zuccoli from the Dept. of Astronomy of the Bologna University still work together with INAF personnel Monica Marra and with Katia Alboresi (INAF contractor).

8 Outreach and educational activities

The model of the Solar System at the Loiano Observatory: the Sun and the inner planets.

People involved at OAB:

- *Scientific staff:* S. Bardelli, R. Bedogni, A. Cappi, P. Ciliegi, G. Clementini, F. Delpino, F. Fusi Pecci, B. Lanzoni, G. Parmeggiani, P. Ranalli, V. Zitelli, E. Zucca.
- *Technical staff:* S. Bernabei, I. Bruni, A. De Blasi, R. Di Luca, O. Diodato, R. Gualandi, C. Pavan.

The OAB is increasingly involved in outreach and educational activities through exhibitions, educational courses, workshops and seminars. Many of these activities, due to the growth of public interest in astronomy and astrophysics, have led to a stable partnership between the OAB, the Astronomy Department of the University of Bologna (AD), the Institute of Radio Astronomy (IRA) and the amateur astronomers of Bologna (Associazione Astrofili Bolognesi, hereafter AAB) and S. Giovanni in Persiceto (Astrofili Persicetani, hereafter AP).

The outreach activities during 2003 were:

- Col Favore del Buio;
- Estate Astronomica Bolognese;
- Con il laser tra le stelle;
- Premio Guido Horn d'Arturo.

The educational activities in the same period were:

- Usciamo a vedere le stelle;
- Parco delle stelle;
- Conferenze della Specola;

In November the important workshop *Stelle di carta* was also held (see Section 12).

8.1 Outreach Activities

8.1.1 Col Favore del Buio

People involved at OAB: G. Parmeggiani, V. Zitelli, A. De Blasi

Eight years ago the collaboration between the OAB and the Councillor for culture of the Province of Bologna led to the creation of *Col Favore del Buio*: a program to visit the telescopes, radiotelescopes and planetarium of the Province.

It is organized by the OAB and proposes visits to the Loiano Observatory, the Radio Astronomy Observatory of Medicina (IRA), the Specola Museum (AD), the amateur observatories of San Giovanni in Persiceto (AP) and Monte San Pietro (AAB), the Planetarium of San Giovanni Persiceto (AP) and the Educational Laboratory of the Bologna Planetarium of the Bologna City Council. Visitors in 2003 were over 30.000. The events at the Loiano Observatory have been especially successful. The schedule for the last year has included more than 52 evening sessions with about 1900 visitors. Views of the most magnificent objects of our sky are organized with the 60cm. This telescope is interesting also by itself because it has kept its original 1930 mechanical structure. After using the telescope, the visitors are invited to observe the sky without instruments, while astronomers introduce them to stars, planets, and black holes. While the 60cm telescope can be visited in the *Col Favore del Buio* event, the 1.52m telescope (G.D. Cassini) is open to the public only the first Saturday of each month and to schools during the day, upon reservation.

8.1.2 Estate Astronomica Bolognese

People involved at OAB: S. Bardelli, R. Bedogni, A. Cappi, P. Ciliegi, F. Delpino, F. Fusi Pecci, B. Lanzoni, G. Parmeggiani, P. Ranalli, I. Bruni, R. Di Luca, R. Gualandi.

The OAB and the AD have organized three exhibitions with the support of the Bologna City Council, in the framework of the summer event *Viva Bologna*:

Serate con il laser ai Giardini Margherita. Two *Visite guidate della volta celeste* have been organized at the Giardini Margherita of Bologna in July and August. A laser beam was used to describe the

constellations in the sky. Those events were led by F. Fusi Pecci. For about 2 hours, with the help of a laser, F. Fusi Pecci taught the visitors how to orientate themselves in the dark sky. More than 400 people attended each performance.

Incontri con l'Astronomia. During the summer ten astronomy conferences have been held in the Cortile d'Ercole of the Palazzo Poggi, Rectorate of the University. Every event has been attended by more than 100 people.

Apertura serale del Museo di Astronomia. The museum, located in the rooms of the ancient Specola (meridian room, turret room and globes room), has been opened for eight evenings with wide public participation.

8.1.3 Con il laser tra le stelle

People involved at OAB: F. Fusi Pecci, G. Parmeggiani, I. Bruni, R. Di Luca, R. Gualandi

Further events with the laser beam were organized at the Giardini Margherita of Bologna (December, more than 300 people), at the S. Giovanni in Persiceto amateur observatory (May and September, each time more than 200 people), and at the soccer field of Loiano (August, more than 200 people).

The events in Bologna and S. Giovanni in Persiceto were led by F. Fusi Pecci, director of OAB, while that in Loiano by B. Marano, director of AD. In each event, with the help of a laser, the visitors were taught how to orientate themselves in the dark sky.

8.1.4 Premio Guido Horn d'Arturo

People involved at OAB: G. Parmeggiani, V. Zitelli, A. De Blasi, R. Di Luca

The OAB in collaboration with the AD, the AAB and with the support of the Italian Astronomical Society (SAIt), has launched a new contest, the *Premio Guido Horn d'Arturo*: amateur astronomers, either individuals or teams, were invited to present a proposal for an astronomical observation to be made at the Loiano 60cm telescope.

From all the received applications, a Jury selected a proposal concerning a photometric study of the Galactic star clusters NGC 129 and NGC 7790.

8.2 Educational Activities

8.2.1 Usciamo a vedere le stelle

People involved at OAB: S. Bardelli, R. Bedogni, A. Cappi, F. Fusi Pecci, B. Lanzoni, G. Parmeggiani, V. Zitelli, E. Zucca, S. Bernabei, I. Bruni, A. De Blasi, R. Di Luca, O. Diodato, R. Gualandi, C. Pavan

During the first week of September, the OAB, in collaboration with the AD, the INAF–Torino Astronomical Observatory, Alenia Spazio Spa, the Associazione per la divulgazione dell'Astrofisica di Torino (ADAS), and with the support of the SAIt, has organized *Usciamo a vedere le stelle*: an educational course for students of the last two years of High Schools. To participate the students had to present a written essay on astrophysical topics. From all applicants, a Jury selected 20 students. The winners, coming from all over Italy, were hosted in Loiano for a week. They followed astronomical courses and observed at the telescopes of the Loiano observatory.

8.2.2 Parco delle Stelle

People involved at OAB: G. Parmeggiani, V. Zitelli, S. Bernabei, I. Bruni, A. De Blasi, R. Gualandi

The *Parco delle Stelle* at the Loiano Observatory is an educational park built by the OAB for the students coming to see the telescopes. Is has been built with a grant from the MIUR. It consists of:

Solar system model. In order to understand the dimensions of our planetary system and the distances to the various planets, the OAB, in collaboration with the AD, has built a model in scale of the Solar System. It starts from the 152cm telescope building and goes along a path in the forest, reaching the dome that hosts the historical 60cm telescope. One meter along this path corresponds to 15 million kilometers. To give a better feeling of the dimensions of

planets and Sun there is a second unit of measure with one centimeter corresponding to 7000 kilometers.

Solar telescope. A Coronado solar telescope allows people to see the Sun in Hα light and understand part of its physical characteristics.

Sundial. A modern sundial has been built to show how the Sun moves in the sky.

Cosmic Calendar. In June 2004 a new exhibit will be opened: Imagine compressing the history of the universe in one year with the Big Bang occurring in the first seconds of New Year's Day, and all our known history occurring in the final seconds before midnight on December 31st. Using this timescale, each month corresponds to a bit more than a billion years.

8.2.3 Conferenze della Specola

People involved at OAB: R. Bedogni, G. Clementini, E. Delpino, F. Fusi Pecci, G. Parmeggiani, R. Di Luca, O. Diodato, C. Pavan

On every first Wednesday of the month, at the Specola, the old Observatory of Bologna in the town center, there is a seminar on astronomical topics. The audience is mainly formed by High School students. On average 80/90 people attend each conference. The texts of the conferences are available on the web page of the Observatory.

8.3 Educational and Public Outreach

A. D'Ercole edits the column *Spigolature astronomiche* for the Giornale di Astronomia.
G. Parmeggiani edits the book review for the Giornale di Astronomia.

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10 Observing Campaigns

Radio Telescopes

1. ATCA (Australia Telescope Compact Array), *Wide - Area Deep Radio Observations of SWIRE/APEX fields*, PI: B. Boyle Co-I: Norris, Jackson, Webster, Ivison, Lonsdale, **P. Ciliegi**, 120 hours, January-February 2004

2. GMRT (India), *Low frequency observations of NGC326*, PI: M. Murgia, Co-I: **de Ruiter** et al., 18 hours, 11-12 July 2003

3. GMRT 235 MHz, 327 MHz, 610 MHz, *Low frequency study of the radio halo in the merging cluster A3562*, PI: T. Venturi, co-I: **S. Bardelli** et al., 20 hours, January-February 2003

4. GMRT 235 MHz, 327 MHz, 610 MHz, 1420 MHz, *Low frequency study of the radio relic in the ongoing cluster merger A2061*, PI: T. Venturi, co-I: **S. Bardelli, E. Zucca** et al., 36 hours, August-October 2003

5. GMRT 1420 MHz, *Radio source birth and recurrent radio activity in cD galaxies*, PI: T. Venturi, co-I: **S. Bardelli** et al., 14 hours, August 2003

6. VLA (U.S.), *Fossil radio galaxies*, PI: M. Murgia, Co-I: **H. de Ruiter** et al., 20 hours, 4–9 December 2003

ESO

VLT

7. ESO VLT+FLAMES, *GTO Italflames – Chemical composition and dynamics of dwarf Spheroidals in the Local Group*, PI: Bonifacio P., Co-I: **M. Bellazzini**, [...], **E. Pancino** et al., 1 night

8. ESO VLT+FLAMES, *Formation and evolution of Galactic Globular Clusters: the first billion years*, PI: Carretta E., Co-I: **A. Bragaglia, E. Pancino** et al., 74 hours, 2003-2004 (service)

9. ESO VLT+FLAMES, *Understanding the blue straggler formation processes in galactic globular clusters*, P.I.: Ferraro F.R., Co-I: [...], E. Carretta, [...], **M. Bellazzini, F. Fusi–Pecci, C. Cacciari, E. Pancino**, Sabbi E., Beccari G., 4 nights

10. ESO VLT+FLAMES, *Settling an homogeneous metallicity scale for stellar clusters in the large magellanic cloud from high resolution spectroscopy*, PI: Ferraro F.R., Co-I.: **L. Origlia**, Testa V., E. Carretta, **F. Fusi–Pecci**, Valenti E, 16 hours

11. ESO VLT+FLAMES, *GTO Italflames – Understanding the chemical enrichment history of massive globular clusters: ω Centauri and M 22*, PI: Ferraro F.R., Co-I: **E. Pancino, M. Bellazzini, L. Origlia, C. Cacciari**, Monaco L, Bonifacio P., 2 nights

12. ESO VLT+FLAMES, *Absolute ages for Globular Clusters with accuracy of $\pm$ 1 Gyr: the fundamental importance of precise reddenings and metallicities*, PI: R. Gratton, Co-I: **A. Bragaglia, M. Bellazzini, G. Clementini** et al., 27 hours, 2004 (service)

13. ESO VLT+FLAMES, *The origin and evolution of metals in the LMC: a novel and powerful constraint to the star formation history*, PI: V. Hill, Co-I: **M. Tosi**, 19 hours, March 2003

14. ESO VLT+FLAMES, *Ital-FLAMES GTO It#4: Multiobject spectroscopy of Galactic Open Clusters of different ages and metallicity*, PI: R. Pallavicini, Co-I: **A. Bragaglia, M. Tosi** et al., 3 nights, 21 May & 01 December 2004, 14 February 2004

15. ESO VLT+FLAMES, *Old Open Clusters as key tracers of the evolution of light elements and the Galactic disk*, PI: S. Randich, Co-I: **A. Bragaglia, M. Tosi** et al., 20 hours, 2004 (service)

16. ESO VLT+FORS1, *Optical identification of faint HELLAS2XMM sources: chasing type 2 QSOs*, PI: F. Cocchia, Co-I: F. Fiore, A. Baldi, N. Carangelo, S. Molendi, **A. Comastri**, **M. Mignoli**, M. Brusa, **P. Ciliegi**, [...], **Vignali C.**, 1.8 nights, March 2004 (visitor)

17. ESO VLT+FORS2, *GMASS: the Galaxy Mass Assembly ultradeep Spectroscopic Survey*, PI: Cimatti, Co-I: Berta, Cassata,

Daddi, di Serego Alighieri, Franceschini, Kurk, **B. Lanzoni**, Vernet, **M. Mignoli, L. Pozzetti**, [...], **G. Zamorani**, 30.3 hours: April 2004 (service)

18. ESO VLT+FORS2, *The first building blocks in the Local Group: probing the oldest stellar populations in Dwarf Galaxies through the metal distribution of the RR Lyrae stars in Sculptor*, PI: **G. Clementini**, Co-I: **A. Bragaglia** et al., 10 hours, 2003 (service)

19. ESO VLT+FORS2, *The age-metallicity relation and star formation history of the SMC: star clusters*, PI: E. Grebel, Co-I: **M. Tosi**, 18.5 hours, P73

20. ESO VLT+ISAAC, *Spectroscopic identification of a new population of super-EROs hosting AGNs*, PI: Maiolino, Co-I: **M. Mignoli, L. Pozzetti**, Brusa, **P. Ciliegi, A. Comastri**, [...], **C. Vignali**, 12 hours, April 2004 (service)

21. ESO VLT+ISAAC, *Supermassive Black Holes in High Redshift Quasars*, PI: A. Marconi, Co-I: D. Axon, [...], **G. Stirpe**, 19.5 hours, 2003-2004

22. ESO VLT+ISAAC, *Unveiling the nature and star formation activity of dusty EROs*, PI: Vernet, Co-I: Cimatti, Daddi, di Serego Alighieri, **M. Mignoli, L. Pozzetti**, Renzini, **G. Zamorani**, 34 hours, April 2003 (service)

23. ESO VLT+UVES, *Detailed chemical properties of field Blue Stragglers Stars: probing the formation mechanism in low-density environments*, PI: Carretta E., Co-I: **A. Bragaglia, C. Cacciari** et al., 25 hours, 2003-2004 (service)

24. ESO VLT+UVES, *The properties of dusty red giants in globular clusters*, van Loon J., **L. Origlia** et al., 2 nights

25. ESO VLT+VIMOS, *A Spectroscopic Study of the Globular Clusters in the Sculptor Spiral Galaxy NGC253*, PI: **C. Cacciari** Co-I: **L. Federici**, S. Galleti, E.V. Held, A. Moretti, 6 hours, June 2003 (service)

26. ESO VLT+VIMOS, *Large Programme: An ESO-SIRTF WIDE-AREA IMAGING SURVEY (ESIS), targeting the history of cosmic transformations of baryons in stars and active nuclei*, PI: Franceschini, Co-I: Vettolani, Held, Lonsdale, **G. Zamorani**, Rowan-Robinson, Smith, Rizzi, **P. Ciliegi**, La Franca, Oliver, Perez-Fournon, **C. Gruppioni** et al., 96 hours, April, August 2003 (service); 20 hours, April 2004 (service)

27. ESO VLT+VIMOS, *An ultra deep IFU spectroscopic coverage of the Hubble Deep Field south*, PI: Giallongo, Co-I: **S. Bardelli, [...], G. Zamorani**, 98 hours: April 2003, 62 hours: April 2004 (service)

28. ESO VLT+VIMOS, *Globular clusters in the outer halo of the Sombrero galaxy*, PI: E.V. Held, Co-I: A. Moretti, **L. Federici**,**C. Cacciari** et al., 13.5 hours, April 2003 (service)

29. ESO VLT+VIMOS, *VIMOS Spectroscopy of the COSMOS 2-square degree ACS Survey Deep Field*, PI: Kneib, Co-I: Scoville, [...], **G. Zamorani, S. Bardelli, A. Cappi, M. Mignoli, L. Pozzetti, E. Zucca**, Marano, Vettolani and the COSMOS team 68 hours: April 2004 (service)

30. ESO VLT+VIMOS, *AN ESO-XMM-SIRTF WIDE AREA SURVEY: the measure of the clustering of AGN, and the nature and evolution of infrared galaxies*, PI: F. La Franca, Co-I: F. Fiore, [...], **A. Comastri**, E. Daddi, **C. Gruppioni**, R. Maiolino, **M. Mignoli**, S. Molendi, G.C. Perola, **L. Pozzetti**, F. Pozzi, G. Rodighiero, H.E. Smith, **Zamorani G.**, 30 hours, April 2004 (service)

31. ESO VLT+VIMOS, *The VIRMOS/VLT Deep Survey (VVDS)*, PI: O. Le Fèvre, G. Vettolani, Co-I: **G. Zamorani, S. Bardelli, A. Cappi, L. Pozzetti, E. Zucca, P. Ciliegi, H. De Ruiter** et al. (VIRMOS Consortium), 19 nights (GTO), February-September 2004

32. ESO VLT+VIMOS, *The VIRMOS/VLT Deep Survey (VVDS)*, PI: O. Le Fèvre, G.Vettolani, Co-I: **G. Zamorani, S. Bardelli, A. Cappi, L. Pozzetti, E. Zucca, P. Ciliegi, H. De Ruiter**

et al. (VIRMOS Consortium), 5 half nights (GTO), December 2003

33. ESO VLT+VIMOS, *A2163: A "pre" and "post" merger?*, PI: S. Maurogordato, Co-I: Benoist, **A. Cappi** et al., 2 nights, may 2004 (visitor)

34. ESO VLT+VIMOS, *Culling K-Band luminous, massive galaxies at z=2*, PI: Renzini, Co-I: Arimoto, Brusa, Broadhurst, Cimatti, **A. Comastri**, Daddi, Ikuta, Ohta, **L. Pozzetti, G. Zamorani**, 34 hours: October 2003 (service)

35. ESO VLT+VIMOS (IFU), *Dynamics at High Redshifts: the Key Role of Integral Field Spectroscopy*, PI: D.Rizzo, co-I: **S. Bardelli, A. Cappi**, A.Zanichelli, **E. Zucca**, 11 hours, March 2003

NTT

36. ESO NTT+SOFI, *Large Programme: The nature and evolution of infrared galaxies: bridging optical and SIRTF-SWIRE data with near-infrared observations of the ELAIS-S1 field*, PI: Cimatti, Co-I: Berta, **P. Ciliegi, A. Comastri**, Daddi, di Serego Alighieri, Fiore, Fontana, Franceschini, **C. Gruppioni**, La Franca, Lonsdale, Maiolino, **M. Mignoli**, Poli, **L. Pozzetti**, Rodighiero, Saracco, Smith, Vernet, **G. Zamorani**, 14 nights, September-Novemeber 2003 (visitor)

37. ESO NTT+SOFI, *Optical/IR emission lines in bright ISO/SIRTF quasars*, PI: Serjeant S., coI: **C. Gruppioni**, T. Morel, 2 nights, October 2003 (visitor)

38. ESO NTT+SOFI, *Public Imaging Survey*, PI: Krautter, Co-I: Arnaud, [...], **G. Zamorani** et al, 18 nights: January, August, October 2003; September 2004 (visitor)

39. ESO NTT+SOFI, *Optical/IR emission lines in bright ISO/SIRTF quasars*, PI: S. Serjeant, Co-I: **C. Gruppioni**, T. Morel, 2 nights, October 2003

3.6m

40. 3.6m+EFOSC2, *Dynamical state and star formation within the bimodal galaxy cluster A2933: wide field imaging and multi–object spectroscopy*, PI: C.Benoist, Co-I: **A. Cappi** et al., 2 nights, October 2003

2.2m

41. ESO 2.2m+WFI, *Completing the pre-FLAMES public survey of the tidally disrupted Sagittarius Dwarf Spheroidal* Ferraro F.R., **M. Bellazzini**, Monaco L., Sabbi E., **E. Pancino**, Valenti E., Bonifacio P., Sbordone L., 8.2 hours

42. ESO 2.2m+WFI, *Large Programme: An ESO-SIRTF WIDE-AREA IMAGING SURVEY (ESIS), targeting the history of cosmic transformations of baryons in stars and active nuclei*, PI: Franceschini, Co-I: Vettolani, Held, Lonsdale, **G. Zamorani**, Rowan-Robinson, Smith, Rizzi, **P. Ciliegi**, [...], **C. Gruppioni** et al 70 hours: April 2003 (service)

43. ESO 2.2m+WFI, *Public Imaging Survey - GALEX and SIRTF Coverage and Completion of the Deep Survey*, PI: Krautter, CoI: Arnaud, [...], **G. Zamorani**, et al, 34 hours, April 2003 (service)

44. ESO 2.2m+WFI, *Public Imaging Survey: WFI Follow-up of XMM-Newton Serendipituous Fields*, PI: Krautter, CoI: Arnaud, [...], **G. Zamorani** et al, 157.5 hours, April-October 2003 (service)

45. ESO 2.2m+WFI, *Search for planetary transits in the metal-rich open cluster NGC 6253 and the surrounding field*, PI: G. Piotto, Co-I: **A. Bragaglia** et al., 10 nights, June 2004

1.52m

46. ESO 1.52m+FEROS *Ground-based characterization of the targets for the COROT space mission*, PI: E. Poretti, Co-I: **A. Buzzoni** and the COROT intl. team, 5 nights, January 2003

TNG

47. TNG+DOLORES, *Getting accurate distances to local-group galaxies*, PI: F.R. Ferraro, Co-I: **M. Bellazzini, L. Origlia, E. Pancino**, 3 nights

48. TNG+DOLORES, *The RR Lyrae star population of the remote Galactic Globular Cluster NGC 2419*, PI: V. Ripepi, Co-I: M. Marconi, I. Musella, M. Di Crescienzo, **G. Clementini** et al., 12 hours, 2003, service

49. TNG+LRS *Do old metal-rich open clusters hide the secret of the UV-upturn phenomenon in elliptical galaxies?*, PI: L. Buson Co-I: **A. Buzzoni**, E. Bertone, 7hours, AOT8 period (service)

50. TNG+LRS, *Structure of the Galactic Halo towards the North Galactic Pole (NGP)*, PI: **C. Cacciari**, Co-I: **A. Bragaglia, A. Buzzoni**, T. Kinman, A. Spagna, 32 hours, Spring 2003 (service)

51. TNG+LRS, *Structure of the Galactic Halo towards the Anticenter*, PI **C. Cacciari**, Co-I **A. Bragaglia, A. Buzzoni**, T. Kinman, A. Spagna, 27 hours, 24-26 Jan 2004

52. TNG+LRS/MOS, *Membership in old open clusters from multislit intermediate resolution spectroscopy: Be 17 and Be 32*, PI: **A. Bragaglia**, Co-I: **M. Tosi**, E.V. Held, L. Di Fabrizio, 18 hours, February 2004 (service)

53. TNG+LRS/MOS, *Spectroscopic follow-up for candidate transiting planets in the open cluster NGC 6791*, PI: G.P. Piotto, Co-I: **A. Bragaglia** et al., 5.5 hours, Spring 2004 (service)

54. TNG+NICS, *Near-Infrared PL and PLC relations of anomalous Cepheids in the dwarf spheroidal galaxy Ursa Minor*, PI: M. Marconi, Co-I: F. Caputo, **G. Clementini** et al., 24.5 hours, 2003 (service)

55. TNG+NICS/DOLORES, **F. Fusi–Pecci, A. Buzzoni, M. Bellazzini, L. Origlia**, Ferraro F.R. et al., *Spectral energy distribution and bolometric corrections of luminous RGB stars in old star clusters*, 30 hours

56. TNG+SARG, *Metal abundances of old open clusters as tracers of Galactic chemical evolution*, PI: **A. Bragaglia**, Co-I: **M. Tosi**, E. Carretta, R. Gratton, 31 hours, Autumn 2003, service

57. TNG+SARG, *Metal abundances of open clusters as tracers of Galactic chemical evolution : NGC 6791, the oldest one*, PI: **A. Bragaglia**, Co-I: **M. Tosi**, E. Carretta, R. Gratton, 2 nights, 24-25 July 2004

58. TNG+SARG *Ground-based characterization of the targets for the COROT space mission*, PI: E. Poretti, Co-I: **A. Buzzoni** and the COROT intl. team, 2 nights, January 2003

Miscellaneous ground based telescopes

59. CTIO 4m Blanco+WFI, *The Oosterhoff Phenomenon In Globular Clusters of the Fornax Dwarf Spheroidal Galaxy*, PI: H. Smith, Co-I: **G. Clementini**, M. Catelan, E. Poretti, E.V. Held, B. Pritzl, 3 nights, 13-15/11/2003

60. JKT+JAG, *RR Lyrae distances to the Sagittarius stream*, PI: F. Prada, Co-I: D. Martinez-Delgado, [...], **G. Clementini**, 7 nights, 1-7 February 2003

61. KECKII+NIRSPEC, *Abundances of Bulge stars and Clusters*, Rich M., **L. Origlia**, 1 night

62. Magellan 6m Clay+MagIC, *SX Phoenicis and RR Lyrae variables in two dense globular clusters of the Fornax dSph galaxy*, PI: M. Catelan, Co-I: **G. Clementini** et al., 3 nights, 12-14 November 2003

63. NOT+AFOSC, *RR Lyrae distances to the Sagittarius stream*, PI: D. Martinez-Delgado, Co-I: F. Prada, Z. Ivezic, L. Di Fabrizio, K. Vivas, R. Zinn, **G. Clementini**; 5 nights, 2003

64. WHT+WYFFOS, *Investigating the nature of Low Luminosity Active Galactic Nuclei (LLAGN)*, PI: D. Trevese, Co-I: F. Vagnetti, **V. Zitelli**, 2 nights, April 2003

FUSE

65. FUSE, *FUV spectra of the most metal-poor star forming dwarf galaxies in the local universe*, PI: A. Aloisi, Co-I: **M. Tosi**, 115 ksec, cycle 5

HST

66. HST+ACS, *Searching for primeval galaxies: the promising case of SBS 1414+437*, PI: A. Aloisi, Co-I: **M. Tosi**, 18 orbits, May 2003

XMM–Newton

67. XMM-Newton, *Exploring the connection between the X-ray properties and recurrent radio activity*, PI: **S. Bardelli**, co-I: **E. Zucca** et al., 43 ks, August 2004

68. XMM-Newton, *Unveiling the nature of hard X–ray selected AGN through XMM–Newton spectroscopy*, PI: M. Brusa, Co-I: **A. Comastri**, C. Vignali, **M. Mignoli**, F. Fiore, F. La Franca, G. Matt, S. Molendi, F. Cocchia, N. Carangelo, A. Baldi, G.C. Perola, **P. Ciliegi**, R. Maiolino, 80 ks, to be scheduled

69. XMM-Newton, *Spatially resolved observation of merging clusters in the Shapley Concentration: A3530*, PI: S. Ettori, Co-I: **S. Bardelli, E. Zucca** et al.; 20,000 sec, January 2004

70. XMM-Newton, *Evolution of AGN in the cosmic web: the HST + VIMOS + SWIRE Cosmos field*, PI: Günther Hasinger, Co-I: **A. Comastri**, [...], **G. Zamorani**, 840 ks, December 2003–December 2004

71. XMM-Newton, *Elusive AGN and the local density of active galaxies*, PI: R. Maiolino Co-I **A. Comastri** et al., 90 ks, Summer 2004

72. XMM-Newton, *Gaseous abundances in M82*, PI: P. Ranalli, Co-I: **A. Comastri**, **L. Origlia**, R. Maiolino, 100 ks, April 2004

Chandra

73. Chandra, *A Chandra survey of Extremely Red Objects*, PI: M. Brusa, Co-I: **A. Comastri**, A. Cimatti, E. Daddi, C. Vignali, **L. Pozzetti**, **M. Mignoli**, D.M. Alexander, 90 ks, June 2004

74. Chandra, *Spatially resolved observation of a major merging event in the Shapley Supercluster* PI: S. Ettori, Co-I: **S. Bardelli, E. Zucca** et al.; 80 ks, March-December 2003

75. Chandra, *Chasing quasar 2*, PI: F. Fiore, Co-I: **A. Comastri**, M. Brusa, **P. Ciliegi**, **M. Mignoli, [...], C. Vignali**, 45 ks, July 2003

76. Chandra, *Unveiling the engine powering OH Gigamaser sources through X-rays. A well-defined Chandra survey*, PI: **C. Vignali**, Co-I: **A. Comastri**, N. Brandt, 27 ks, December 2003

11 Positions held in working groups and science policy committees

- **Bardelli S.**

  - Board of Directors (since January 17, 2002): member

- **Bellazzini M.**

  - Board of Directors (since January 17, 2002): member

- **Bragaglia A.**

  - ESO OPC Panel D "Stellar Evolution" (since october 2003): member

- **Buzzoni A.**

  - Associate Astronomer at the Telescopio Nazionale Galileo, La Palma (Spain)

- **Cacciari C.**

  - 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

- **Comastri A.**

  - ESA: XEUS (X-ray Evolving Universe Spectroscopy) Astrophysics Working Group: member

  - ESA: XMM–*Newton* User Group: member

- **de Ruiter H.**

  - Expert evaluator of the European Union Marie Curie Training and Research Networks

  - Local scientific coordinator of the European Union program "Cosmolab" in the framework of the "Information Society and Technologies (IST)" programme

- **Fusi Pecci F.**

  - Director of the Bologna Observatory

  - INAF Dip.1: member of the Board

  - INAF Dip.3: member of the TS Committee

  - Cagliari Astronomical Observatory: member of the Board

  - Sardinia Radio Telescope: member of the Board

  - Consiglio Fondazione TT1 (Telescopio Toppo): member

- **Mignoli M.**

  - Organizer of the Observatory "*Thursday Seminars*"

- **Origlia L.**

  - TNG Time Allocation Commettee member

  - Principal Investigator of the GIANO project

- **Pozzetti L.**

  - ESO Observing Programmes Committee (OPC), panel A (cosmology): member

- **Sancisi R.**

  - Scientific Technical Committee, ESO, Garching: member

  - TNG Time Allocation Committee member

  - Board of Directors: member

- **Tinti F.:**

  - Board of Directors: member

- **Tosi M.**

  - Deputy Director of the Bologna Observatory

  - Space Telescope Users Committee: ESA member

  - *Local Late Galactic Evolution* Group, International Space Science Institute (ESA), Berna (since 1998): member

  - INAF Working Group for the Macro–Area *Stars and Interstellar Medium* : coordinator

  - INAF Working Group for the Equal Opportunities: member

  - PhD in Astronomy at the University of Bologna, Collegio dei Docenti: external member

  - INAF committee for the selection of post-doctoral fellowships: member

  - National Coordinator of MIUR-Cofin project

- **Zamorani G.**

  - ESO : VIRMOS Science Team : member

  - ESO: Survey Working Group : member

  - XMM: Time Allocation Committee: Survey panel : chairman

  - SAX: Science Steering Committee (1999 - 2002): member

  - INAF: Comitato di Consulenza Scientifica: chairman

- **Zitelli V.**

  - Board of Directors: member

  - Coordinator of Loiano telescopes

  - Member of the TNG working group site test

  - Bologna University – Teacher of "Laboratorio di tecniche astrofisiche", AA 2002/2003

12 Organization of Workshops

12.1 Bologna Workshop on Stellar population synthesis models and cosmology

People involved at OAB: L. Pozzetti, M. Tosi, F. Fusi–Pecci

In October 31st 2003 a workshop on "Stellar population synthesis models and cosmology" was held at the OAB on the occasion of the visit of Prof. G. Bruzual, director of *Centro de Investigationes de Astronomia*, and one of the major expert of population synthesis models. The most active Italian experts on this specific field, coming from different Italian and international institutes, were invited. The workshop was intended to discuss the most updated versions of synthesis models and to compare the opinions of different leading experts, both theorists and observers, on several open questions, such as stellar populations in elliptical galaxies, with particular interest on Lick indices and alpha-enhancements, as well as on stellar populations in clusters and high-redshift galaxies and on the photometric estimate of the masses. The day was organized with several short presentations by the participants (listed below), a talk by G. Bruzual, and interesting discussions on both observational data and models.

List of presentations:

- C. Chiosi: "Star formation in Ellipticals"
- R. Tantalo: "Lick Indices and enhancement"
- L. Piovan: "Effects of dust around AGB stars"
- A. Buzzoni: "Beyond the Lick Indices"
- **G.A.Bruzual: "Population Synthesis of Galaxies at the Resolution of 2003"** (Talk)
- A. Bressan: "Models in the FIR"
- C. Maraston: "Last news on Synthesis models"
- O. Straniero: "White-dwarfs"
- A. Renzini: "Two Spheroids, MW and M31"

- B. Poggianti: "Stellar population in clusters"
- L. Pozzetti: "Stellar population at high-redshift"
- S. Berta: "Estimation of the Galaxy Stellar-Masses"

List of partecipants: Angeretti L., Annibali F., Berta S., Bressan A., Buzzoni A., Chiosi C., Cimatti A., **D'Ercole A.**, **Fusi Pecci F.**, Greggio L., Maraston C., Pancino A., Piovan L., Poggianti B., **Pozzetti L.**, **Origlia L.**, Renzini, A., Romano D., Straniero, O., Tantalo R., **Tosi M.**, **Zamorani G.**

12.2 Bologna Workshop on Stelle di Carta

People involved at OAB: A. Cappi, F. Fusi Pecci, G. Parmeggiani, A. De Blasi, R. Di Luca, O. Diodato, C. Pavan

On November 27th and 28th the OAB and the AD have organized, with the support of INAF, SAIt, and University of Bologna, the workshop *Stelle di carta: la ricerca astronomica e i media in Italia.*

The aim of workshop was to serve as an informal forum for the discussion of topics related to the present and future relationship between the astronomical community and the media. Eighty people attended the workshop where, apart from the astronomers, the media world was present with newspaper and television journalists. The program of the workshop was as follows:

STELLE DI CARTA: LA RICERCA ASTRONOMICA E I MEDIA IN ITALIA

Bologna, 27-28 novembre 2003

Programma

•) Giovedì 27 Novembre - Mattina

9:30 - Saluto del Direttore dell'Oss. Astronomico di Bologna
Saluto del rappresentante dell'Universitá di Bologna
Intervento del rappresentante del Miur

Dall'ufficio stampa alla prima pagina

Modera: **Luca Tancredi Barone**

9:50-10:15 **Fabio Pagan:** La scienza sui giornali: il caso Boomerang

10:15-10:40 **Franco Foresta Martin:** La macchina mediatica

10:40-10:55 Discussione

Coffee break (20 minuti)

11:15-11:40 **Lars Lindberg Christensen:** The ideal communi cation office

11:40-12:05 **Enrica Battifoglia:** Le agenzie di stampa e il flusso mediatico

12:05-12:30 **Laura La Posta:** La scienza "quotidiana"

12:30-12:55 **Piero Bianucci:** Dall'ufficio stampa alla prima pagina

12:55-13:10 Discussione

•) Giovedì 27 Novembre - Pomeriggio

L'astronomia sulle riviste

Modera: **Giangiacomo Gandolfi**

14:30-14:55 **Marco Cattaneo:** La scienza sulle Scienze

14:55-15:20 **Andrea Parlangèli:** Comunicare su un periodico di scienza e di successo

15:20-15:35 Discussione

Coffee break (20 minuti)

La scienza e il pubblico

Modera: **Stefano Giovanardi**

15:55-16:20 **Pietro Greco:** La percezione pubblica della scienza

16:20-16:45 **Fabiana Fini:** La percezione accademica del pubblico: scienziati e media

16:45-16:55 **Eva Benelli:** Siti web istituzionali: EpiCentro ha fatto centro

16:55-17:10 Discussione, e a seguire

Tavola rotonda: Spazio agli astronomi

Modera: **Luca Tancredi Barone**

The Chairman of Sait, and those representing, or in charge of outreach in the Institutes and Observatories present the relevant activities of their individual institutions and exchange views with journalists about their experiences of communication with the media world. Each participant is awarded 5 minutes and is encouraged to use at most 3 slides for his/her presentation.

20:30 : Cena sociale

•) Venerdí 28 Novembre - Mattina

La scienza in onda

Modera: **Stefano Sandrelli**

9:30-10:00 **Silvia Rosa-Brusin:** Scienza e Tv: il caso di Leonardo

10:00-10:30 **Giosuè Boetto Cohen:** Scienza e TV: il caso di RAI Educational

10:30-11:00 **Barbara Gallavotti:** Scienza e Tv: il caso di Ulisse

11:00-11:15 Discussione

Coffee break (15 minuti)

11:30-12:00 **Sylvie Coyaud:** Scienza e radio: anche i giornalisti, nel loro piccolo

12:00-12:15 Discussione

Tirando le somme dell'incontro

Modera: **Giangiacomo Gandolfi**

12:15-12:45 **Giovanni Caprara e Flavio Fusi Pecci:** discussione

•) Venerdí 28 Novembre - Pomeriggio

15:00-15:30 **Piero Benvenuti:** Ruolo e iniziative dell'Inaf nel campo della comunicazione

A seguire, tavola rotonda:

Verso un ufficio stampa dell'INAF

Modera: **Leopoldo Benacchio**

The directors of the Institutes formerly in CNR and of the Observatories, those in charge of outreach in the Institutes/Observatories and any interested journalists are all invited to participate. The aim of this open debate is to discuss the guidelines for efficient communication with the media, and to define common intents, on the basis of the document presented by the relevant INAF committee.

Sessione di poster

Each INAF Institute and Observatory may present a standard-size poster (technical details will be provided elsewhere) describing its scientific and/or outreach activities.

13 Seminars and visiting astronomers

1. January 16, 2003, **Dario Trevese** (Dipartimento di Fisica - Universita' di Roma "La Sapienza"), *Variabilita' del Continuo Ottico-UV dei Nuclei Galattici Attivi*

2. January 30, 2003, **Vincent Icke** (Sterrewacht Leiden, NL), *Hydrodynamics from one to three dimensions*

3. February 4, 2003, **T.D. Kinman** (NOAO/KPNO, Tucson, USA), *Preston's Blue Metal-Poor (BMP) Stars*

4. February 13, 2003, **Paolo Mazzali** (INAF – Osservatorio Astronomico di Trieste), *Hypernovae and Gamma Ray Bursts*

5. February 27, 2003, **Massimo Meneghetti** (Dipartimento di Astronomia, Università di Padova), *Le proprietà degli archi gravitazionali come strumento cosmologico*

6. March 6, 2003, **Elena Pancino** (INAF-OABo & Dipartimento di Astronomia, Bologna), *Popolazioni stellari multiple in Omega Centauri*

7. March 20, 2003, **Christian Marinoni** (Lab. d'Astrophysique, Marseille, France), *Rivelazione dell'Energia Oscura mediante redshift survey profonde*

8. March 27, 2003, **Horace Smith** (Department of Physics and Astronomy - Michigan State University, USA), *RR Lyrae Stars and Oosterhoff Groups*

9. April 3, 2003, **Steinn Sigurdson** (Department of Astronomy and Astrophysics, Pennsylvania State University, USA), *PSR 1620-26: an unusual triple revealed*

10. April 29, 2003, **Alessia Gualandris** (Astronomical Institute "Anton Pannekoek' & Section Computational Science – University of Amsterdam, NL), *N-body simulations of stars escaping from the Orion nebula*

11. May 15, 2003, **Giorgio Bianciardi** (Università degli Studi di Siena), *L'origine della vita nel cosmo*

12. May 22, 2003, **Eline Tolstoy** (Kapteyn Institute - Rijksuniversiteit Groningen, NL), *Dwarf Galaxies: Important Clues to Galaxy Formation*

13. May 29, 2003, **Francesca D'Antona** (INAF - Osservatorio Astronomico di Roma), *Necessità e modalità dell'autoinquinamento negli Ammassi Globulari*

14. June 5, 2003, **Jacqueline van Gorkom** (Department of Astronomy, Kapteyn Institute, NL), *The Fate of Gas in Merger Remnants: an HI perspective*

15. June 12, 2003, **Marco Limongi** (INAF - Osservatorio Astronomico di Roma), *The (still small) zoo of the Extremely Metal Poor Stars: what do they tell us about the first stellar generation?*

16. September 18, 2003, **Tommaso Treu** (California Institute of Technology - Astronomy Department, USA), *The dark halos of early-type galaxies and the Hubble constant*

17. September 25, 2003, **Manuela Magliocchetti** (SISSA - Astrophysics Division - Trieste), *How many galaxies can fit a dark matter halo? Constraints on their halo occupation number and spatial distribution from the 2dF Redshift Survey.*

18. October 2, 2003, **Gian Luigi Granato** (INAF – Osservatorio Astronomico di Padova), *A Physical model for the co-evolution of QSOs and their spheroidal hosts*

19. October 9, 2003, **Matteo Viel** (Institute of Astronomy – University of Cambridge, UK), *The Lyman-alpha forest as a cosmological probe*

20. October 17, 2003, **Lodewijk Woltjer** (INAF – Osservatorio Astronomico di Arcetri), *The Absorbing Torus in AGN*

21. October 23, 2003, **Stefano Ettori** (European Southern Observatory – Garching, DE), *Confrontando ammassi di galassie vicini e lontani: proprietà fisiche e relazioni di scala*

22. October 31, 2003, **Gustavo Bruzual** (Centro de Investigaciones de Astronomia (CIDA) Merida, Venezuela), *Population Synthesis of Galaxies at the Resolution of 2003*

23. November 6, 2003, **Mercedes Filho** (Istituto di Radioastronomia (IRA-CNR), Bologna), *Nuclear Activity in Nearby Galaxies*

24. November 13, 2003, **Rob Swaters** (Department of Physics and Astronomy – Johns Hopkins University, US), *Dwarf Galaxies and CDM: A Core Problem*

25. November 27, 2003, **Andrea Merloni** (Max-Planck-Institute für Astrophysik, Garching, DE) *The fundamental plane of black hole activity and the cosmological history of accretion*

26. December 2, 2003, **Brian Chaboyer** (Dartmouth College – Hanover, NH, USA), *The Evolution of Metal-Poor Stars*

27. December 4, 2003, **Vincenzo Mainieri** (Max-Planck-Institut fuer extraterrestrische Physik (MPE), DE), *Deep X-ray surveys: beyond the optical spectroscopic limit and a new X-ray luminosity function for AGN*

13.1 Visiting astronomers at the Observatory

1. E. Tolstoy (Groeningen, NL), May 2003
2. J. van Gorkom (Kapteyn Institute, Groningen), June 2003
3. O. Ilbert and L. Tresse (LAM, Marseille), July 2003
4. E. Bertone (INAOE, Puebla, Mexico), September 2003
5. T.S. van Albada (Kapteyn Institute, Groningen), October 2003
6. G. Bruzual (Centro de Investigationes de Astronomia, Merida, Venezuela), October 2003

14 "Laurea" thesis

March 2003

1. Matteo Barnabé, *Modelli Stazionari per il Gas Extra-planare nelle Galassie a Spirale* (**R. Sancisi**)

2. Diego Savalli, *Modelli di evoluzione chimica della Galassia* (B. Marano, **M. Tosi**)

July 2003

3. Angela Bongiorno, *La Survey VIRMOS: analisi fotometrica del campo profondo* (B.Marano, **E. Zucca**)

4. Francesca Civano, *Analisi spettrale di sorgenti con alto rapporto X-ottico nelle survey profonde di Chandra* (G. Palumbo, **A. Comastri**, M. Brusa)

5. Erika De Simone, *Le SED degli ammassi globulari di M31: confronto fra osservazioni e modelli teorici* (F. Ferraro, **F. Fusi Pecci**, **M. Bellazzini**,**A. Buzzoni**,**L. Federici**)

6. Claudia Greco, *La popolazione delle variabili di campo e ammasso nella galassia sferoidale nana Fornax* (B. Marano, **G. Clementini**, E.V.Held, E. Poretti)

7. Erika Taribello, *Metallicità delle variabili RR Lyrae nella Grande Nube di Magellano* (F.Bonoli, **G. Clementini, A. Bragaglia**)

October 2003

Enrico Tagliati, *Radiogalassie estese in ammassi in interazione* (C.Fanti, T.Venturi, **S. Bardelli**)

December 2003

8. Silvia Bonoli, *Il Piano Fondamentale delle Galassie Ellittiche: effetti della rotazione*, (L. Ciotti., **B. Lanzoni**)

9. P. Antonio Carusillo, *Età e metallicità di ammassi aperti vecchi: il caso di Be29* (F. Bònoli, **M. Tosi**)

10. Fiore De Luise, *Studio fotometrico dell'ammasso aperto Melotte 71* (F.R. Ferraro, **A. Bragaglia, M. Tosi**)

"Laurea" in other departments

February 2003

11. Claudia Veronica Barbieri, *Nuove Proprietà delle Curve di Rotazione nelle Galassie a Spirale: il Caso di NGC 4559* (Università degli Studi di Milano, **R. Sancisi**)

15 PhD theses

1. **Luca Angeretti**, *Star formation histories of nearby galaxies*, II year (advisors: **M. Tosi**, B. Marano)

2. **Lara Baldacci**, *Variable stars and stellar populations in Local Group dwarf galaxies*, II year (advisors: **G. Clementini**, L. Gregorini)

3. **Marcella Brusa**, *Physics and evolution of the sources of the X–ray and infrared backgrounds*, III year (advisors: B. Marano, **A. Comastri**)

4. **Silvia Galleti**, *The distance and stellar population of the Andromeda galaxy and its satellites*, I year (advisors: F.R. Ferraro, **M. Bellazzini**, **F. Fusi Pecci**)

5. **A. Marcolini** *Hydrodynamical simulations of starburst galaxies*, I year (advisors: **A. D'Ercole**, F. Brighenti)

6. **Lorenzo Monaco**, *Stellar Populations in the Galactic halo*, III year (advisors: F.R. Ferraro, **M. Bellazzini**, **E. Pancino**)

7. **Piero Ranalli**, *High energy emission properties of starburst galaxies*, III year (advisors: G. Setti, **A. Comastri**)

8. **Antonio Sollima**, *The star formation and chemical evolution history of Omega Centauri*, I year (advisors: F.R. Ferraro, **M. Bellazzini**, **E. Pancino**)

9. **Elena Valenti**, *Stellar populations in the Galactic bulge*, I year (advisors: F.R. Ferraro, **L. Origlia**)

Foreign PhD theses

1. **Rense Boomsma**, *HI Holes and High Velocity Gas in Spiral Galaxies* Groningen University (advisor: **R. Sancisi**)

2. **Edo Noordermeer**, *Dark Matter in Early-Type Spiral Galaxies* Groningen University (advisor: **R. Sancisi**)

16 Post-Doctoral, Post-Laurea fellowships and Contracts

1. **Lara Baldacci**, Post Laurea fellow
2. **Giacomo Beccari**, Post Laurea contract
3. **Emanuela Calabrese**, Post Laurea fellow
4. **Francesca Civano**, Post Laurea fellow
5. **Erika De Simone**, Post Laurea contract
6. **Filippo Fraternali**, Post Doctoral contract
7. **Simona Giacintucci**, Post Laurea contract
8. **Claudia Greco**, Post Laurea fellow
9. **Barbara Lanzoni**, Post Doctoral fellow
10. **Matteo Lombini**, Post Laurea fellow
11. **Henry McCracken**, Post Doctoral contract
12. **Marcella Maio**, Post Laurea contract
13. **Francesca Marini**, Post Laurea contract
14. **Silvia Marinoni**, Post Laurea contract
15. **Lorenzo Monaco**, Post Laurea fellow
16. **Ilario Nardinocchi**, Post Laurea contract
17. **Elena Pancino**, Post Doctoral fellow
18. **Andrea Possenti**, Post Doctoral fellow
19. **Donatella Romano**, Post Doctoral fellow
20. **Emanuel Rossetti**, Post Laurea fellow
21. **Antonio Sollima**, Post Laurea fellow

22. **Christian Vignali**, Post Doctoral fellow

23. **Matteo Vocale**, Post Laurea contract

17 Budget information

Il bilancio preventivo per l'anno 2003 è stato approvato dal Consiglio di Osservatorio (CdO) il 20 Dicembre 2003, secondo criteri di cassa. Quello consuntivo il 31 Marzo 2004.

Nel corso dell'anno sono state apportate variazioni di bilancio in occasione di cinque sedute del CdO, essenzialmente per prendere in carico nuove entrate (ASI, MIUR, etc.) o per apportare adeguamenti tecnici in alcuni capitoli di spesa.

Le Tabelle 1 e 2 riportano in modo estremamente schematico il quadro delle entrate e delle spese (in migliaia di euro).

Table 1: **ENTRATE (in K-euro)**

descrizione	Previsioni defintive	Riscosse
Avanzo di cassa	5.806	——
Trasferimenti INAF	3.760	3.760
Trasferimenti INAF vincolati	183	183
Partite di giro	1.550	841
Totale	11.299	4.784

Il conto consuntivo si compone del rendiconto finanziario, della situazione amministrativa e dell'elenco dei crediti e dei debiti al 31 dicembre 2003. Dalla situazione amministrativa si evince l'avanzo di cassa definitivo al 31 dicembre 2003, pari a euro 5.468.163,45.

L'elenco dei crediti e dei debiti (qui non riportato per brevità, ma disponibilie) rappresenta l'ammontare delle operazioni in sospeso alla chiusura dell'esercizio, la cui manifestazione finanziaria avverrà nel corso del 2004.

L'avanzo è stato definito come vincolato in quanto ripartito tra capitoli la cui copertura deve essere garantita sia per rispetto dei contratti e degli impegni vigenti, sia in osservanza a norme di legge.

Come si evince rapidamente anche dalle Tabelle qui riportate, gran parte dell'avanzo è dovuto a 4.438 K-euro lì confluiti a causa

Table 2: **SPESE (in K-euro)**

descrizione	Previsioni defintive	Pagate
Spese per organi	25	21
Oneri per Personale	3206	2958
Acquisto di beni e servizi	207	185
Correnti per la ricerca	553	376
Correnti per la ricerca vincolate	572	310
Oneri finanziari e tributari	2	1
Spese diverse	225	0
Acquisti e manutenzioni straord.	134	40
Investimento per la ricerca	189	104
Investimento per la ricerca vincolate	131	114
Edilizia (impegno vincolato)	4504	154
Partite di giro	1550	859
Totale	11.299	5.122

dell'impegno assunto per la compartecipazione alla costruzione della nuova sede congiunta OAB -Dipartimento di Astronomia, al Navile.

Il resto dell'avanzo è dovuto sostanzialmente a due voci principali:

- fondi di ricerca aventi durata pluriennale e destinazione vincolata, e accantonamenti per acquisti, interventi, manutenzioni etc. su base pluriennale (cioè non attuabili con le risorse disponibli in un unico esercizio finanziario);
- fondo di riserva o fondi vincolati per norme di legge.