Pontificia Universidad Católica de Chile

Departamento de Astronomía y Astrofísica

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1 Introduction

The Departamento de Astronomía y Astrofísica (Astronomy and Astrophysics Department, DAA) is one of the two academic divisions of the Faculty of Physics of Pontificia Universidad Católica de Chile (PUC). This faculty offers undergraduate (Licenciatura) degrees with major in Astronomy or Physics, and Ph.D. and Master's programs in Astrophysics or Physics. The mission of the DAA is to be a center of excellence for studies in Astronomy and Astrophysics, covering a broad range of areas of observational and theoretical astrophysics, and to prepare the next generations of students that will profit from the superb observational facilities available to Chilean astronomers and their collaborators. In this report, we review the main activities at DAA from September 2002 until September 2003.

2 Personnel

2.1 Changes in 2002/2003

Arrivals

Dr. A. Drake arrived from the Lawrence Livermore National Laboratory, USA, to start the Chilean residence period of his joint Princeton–PUC postdoctoral position. Dr. J. Borissova arrived from the Institute of Astronomy of the Bulgarian Academy of Sciences, Bulgaria, to take a FONDAP postdoctoral position. Dr. M. Zoccali arrived from ESO, Chile, to start the Chilean residence period of her joint Princeton–PUC postdoctoral position.

Departures

Dr. P. Hall left the DAA to join Princeton University research staff for the final year of his joint postdoctoral position (see 5). Dr. S. Ellison finished her ESO postdoctoral position with a jointly supported year of residence at the DAA and moved to the University of Victoria, Canada, to take a faculty position. Dr. R. Cabanac finished his ESO postdoctoral position with a jointly supported year of residence at the DAA and moved to the CFHT Corporation, in Hawaii, to take a resident astronomer position.

2.2 DAA Faculty

- Dr. Felipe Barrientos, Assistant Professor (Ph.D. University of Toronto, 1999) – *Galaxy evolution and morphology. Elliptical galaxies. Clusters of galaxies. Observational cosmology.*
- Dr. Márcio Catelan, Associate Professor (Ph.D. Universidade de São Paulo, Brazil, 1996) – *Stellar evolution. Globular clusters. RR-Lyrae variable stars.*
- Dr. Alejandro Clocchiatti, Associate Professor (Ph.D. University of Texas at Austin, 1995) – *Supernovae, near and far. Radiative Transfer. Cosmology.*
- Dr. Gaspar Galaz, Assistant Professor (Ph.D. Université de Paris, France, 1998) – *Stellar population in galaxies. Galaxy evolution. Statistical properties of the galaxy distribution.*
- Dr. Leopoldo Infante, Associate Professor and DAA Chairman (Ph.D. University of Victoria, Canada, 1990) – *Galaxy and structure evolution. Pairs, groups and clusters of galaxies. LSB, dwarf and star forming galaxies in relation to environment. High-z QSOs. Correlation functions.*
- Dr. Dante Minniti, Associate Professor (Ph.D. University of Arizona, 1993) – *Globular clusters. Stellar populations and evolution. Extrasolar planets. Galaxy formation. Galactic structure. Gravitational microlensing.*
- Dr. Hernán Quintana, Full Professor (Ph.D. Cambridge University, 1973) – *Observational astrophysics. Clusters of galaxies. Interacting galaxies. Large scale structure.*
- Dr. Andreas Reisenegger, Associate Professor (Ph.D. Caltech, 1993) – *Theoretical Astrophysics. Neutron stars. Clusters of galaxies.*

2.3 Postdoctoral Fellows 2002/2003

The following scientist held postdoctoral positions at the DAA during the reported period.

- Dr. Jordanka Borissova (Institute of Astronomy, Bulgarian Academy of Science, 1990), *Variable Stars, Star Clusters, Stellar Evolution*
- Dr. Remi Cabanac (Ph.D. Université Laval, 1998), *Large scale structures, gravitational lensing, compact star forming galaxies, liquid mirror telescopes.*
- Dr. Andrew Drake (Ph.D. Australian National University, 2001), *Planet searches, Microlensing, Galactic Structure.*
- Dr. Sara Ellison (Ph.D. Cambridge University, 2000), *Galaxy clustering near QSOs. Metal enrichment of the Lyman Alpha Forest, and metallicity evolution of DLAs. Gamma ray bursts.*
- Dr. Patrick Hall (Ph.D. University of Arizona, 1995), *QSOs (Normal, Unusual, BAL & Reddened). High–z galaxies and their stellar populations. High–z AGNs.*

- Dr. Andrew Stephens (Ph.D. Ohio State University, 2001), *Globular Clusters. Galactic Bulge.*

- Dr. Manuela Zoccali, (Ph.D. Università di Padova, 2000), *Old Stellar Populations, Globular Clusters, Galactic Bulge, Initial Mass Function.*

Support for the postdoctoral fellows comes from combinations of DAA funds, grants from the Joint ESO–Chile Committee for the Development of Astronomy in Chile, the Chilean Andes Foundation, and the FONDAP program (see 5).

2.4 Technical Staff and Assistants

- Dr. Maurizio Baffico (Ph.D. in Physics, Universidad de Chile, 1997) *Teaching Observatory development and maintenance.*

- Lic. Rodrigo Fernández (B.S. in Astronomy, Pontificia Universidad Católica, 2003), *Research Assistant for A. Reisenegger.*

- Lic. Gisela Hertling (B.S. in Physics, Pontificia Universidad Católica, 1989), *FONDAP Research Assistant.*

- Lic. Claudio Navarro (B.S. in Astronomy, Pontificia Universidad Católica, 2002), *Research Assistant for M. Catelan.*

- Ing. Juan Véliz (Software Engineer, Universidad de Chile, 1991), *System Manager. Software Specialist.*

2.5 Recognitions, Awards and Sabbaticals

H. Quintana was awarded a 2002 Guggenheim Foundation Fellowship. He took a sabbatical leave between 1 September 2002 and 1 July 2003, and spent part of this time visiting the Department of Astrophysical Sciences at Princeton University.

3 Academic Programs

3.1 Graduate Program and Students 2002/2003

3.1.1 New Graduate Program

In June 2003, the PUC University Council approved the splitting of the old graduate program in physics into two new mentions: Astrophysics and Physics. The PhD in Astrophysics has four core courses: Physical Processes in Astrophysics, Stellar Astrophysics, Extragalactic Astrophysics, and a "Topics" course. Students have to start research projects during the first semester in school. The DAA and the Department of Physics handle admissions jointly. Students specify their interest when applying to the program.

3.1.2 Graduate Students

Students enrolled during this period were:

Paula Benavídez (B.S. in Astronomy, Universidad Nacional de San Juan, Argentina); Axel Bonačić (B.S. in Physics, Pontificia Universidad Católica de Chile); Rodrigo Contreras (B.S. in Engineering, Pontificia Universidad Católica de Chile); Sergio Flores (B.S. in Astronomy, Universidad Nacional de San Juan, Argentina); José Gallardo (B.S. in Physics, Universidad de Chile); Alejandro García (B.S. in Astronomy, Pontificia Universidad Católica de Chile); Matías Gómez (B.S. in Physics, Universidad Católica de Valparaíso, Chile); Erika Labbé (B.S. in Physics, Universidad Técnica Federico Santa María, Chile); Patricio Lagos (B.S. in Physics, Pontificia Universidad Católica de Chile); M. Cristina Manterola (B.S. in Astronomy, Pontificia Universidad Católica de Chile); Marcelo Mora (B.S. in Physics, Pontificia Universidad Católica de Chile); Noelia Noel (B.S. in Astronomy, Universidad Nacional de San Juan, Argentina); Fernando Peña (B.S. in Astronomy, Pontificia Universidad Católica de Chile); Mario Riquelme, (B.S. in Astronomy, Pontificia Universidad Católica de Chile); Mario Soto (B.S. in Physics, Universidad de Chile).

3.1.3 Visiting Graduate Students

Steffen Mieske, (M.S. in Physics, University of Bonn, Germany); Lianne Muijres, (B.S. in Astronomy, University of Nÿmegen; Netherlands); Oak-Kyoung Park, (M.S. in Astronomy, Australian National University).

3.1.4 New Admissions

Daniela Villegas, and Juan Esteban González (both with a B.S. in Astronomy from PUC) were admitted to the Ph.D. program in August 2003.

3.1.5 Degrees obtained, Student News & Flux

- Axel Bonačić finished his Master's Degree, defending his Thesis entitled *Millisecond pulsars with r-modes as steady gravitational radiators.* He then moved to the University of Utrecht, Netherlands, to start a Ph.D. program.

- José Gallardo finished his Master's Degree, defending his Thesis entitled *Selection and Characterization of Extrasolar Planet Candidates orbiting Main Sequence Stars.* He then moved to Toulouse, France, to start a Ph.D. program.

Erika Labbé spent the whole year in residence at the Obs. de Toulouse, France.

Mario Riquelme obtained a graduate fellowship from CONICYT (January 2003), and passed the qualifying exam (August 2003).

Paula Benavídez withdrew from the program and moved to Universidad de Alicante, Spain. Alejandro García withdrew from the program and moved to the University of Nottingham, England. Noelia Noel withdrew from the program and moved to Universidad de La Laguna, Spain. Fernando Peña withdrew from the program and moved to University of Toronto, Canada.

3.2 Undergraduate Program and Licence Thesis

The PUC undergraduate program in Astronomy currently has ∼100 students, who are consistently drawn

from the top 2% of the ∼200,000 high school seniors who take the nationally administered entrance examination (PAA).

Undergraduate students work full time the last semester of the program on a research project under the supervision of a faculty member, sometimes with a co-supervisor from another institution. Students who finished their degree during this period reported, the subject of the research program, and their supervisor(s) are:

- Rodrigo Fernández *Thermal evolution of neutron stars with rotochemical heating* – (A. Reisenegger)
- Juan Esteban González *Study of clusters of galaxies in the Sloan Digital Sky Survey* – (H. Quintana)
- M. Cristina Manterola *IR Color Gradients in Cluster Elliptical Galaxies at* $z \sim 1$ – (F. Barrientos)
- Claudio Navarro *Flattening of Globular Clusters and the Second Parameter Problem* – (M. Catelan)
- José Luis Prieto *An Independent Hubble Diagram with High Redshift SNe* – (A. Clocchiatti).
- Manuchehr Taghizadeh *Models of barotropic stars with variable rotation* – (A. Reisenegger)
- Sergio Vera *Characterization of CTIO's* OCEANOPTICS *Bench Spectrograph* – (N. Suntzeff, CTIO; and F. Barrientos).
- Alvaro Villalobos *A Study of nuclei of a selected sample of LSB galaxies* – (G. Galaz)
- Daniela Villegas *Spectroscopy of Globular Clusters in Centaurus A* – (D. Minniti)

4 DAA Visitors and Colloquium Program

The DAA has a vigorous visitors program that profits from the large number of astronomers that come to the international observatories on observing trips and can, in turn, benefit from longer periods of activity in Chile, sometimes in between different runs. The DAA serves them as an academic home ground in Chile. Binational programs to foster academic exchange with Argentina and individually funded programs that support visitors from any national or foreign institution, have provided a steady flux of visitors. Senior visitors who stay more than a semester, or student visitors who stay in residence at PUC more than nine months qualify as Chilean astronomers for the purposes of telescope time request.

During the reported period, the following astronomers stayed with us:

- Dr. Omar Benvenuto (La Plata National University, Argentina), visited A. Clocchiatti.
- Dr. Frederic Courbin (Liege University, Belgium) visited D. Minniti.
- Dr. Holland Ford (John Hopkins University) visited L. Infante.
- Dr. José Funes (Vatican Research Group, University of Arizona, USA) visited D. Minniti.
- Dr. Peter Garnavich (Notre Dame University, USA) visited A. Clocchiatti.
- Dr. Mike Gladders (OCIW) visited F. Barrientos.
- Dr. Marten van Kerwijk (University of Toronto, Canada), visited A. Reisenegger.
- Dr. Marcus Kissler (ESO, Germany) visited D. Minniti.
- Dr. Shrinivas Kulkarni (Caltech, USA), visited A. Reisenegger.
- Dr. Duccio Macchetto (STScI, USA) visited D. Minniti.
- Dr. Nidia Morrell (CARSO, Las Campanas, Chile) visited D. Minniti.
- Dr. Hernán Muriel (Obs. de Córdoba, Argentina) visited D. Minniti & H. Quintana.
- Dr. Marina Rejkuba (ESO, Germany) visited D. Minniti.
- Dominique Proust (Obs de Meudon, France) visited H. Quintana.
- David Schade (HIA, Canada) visited F. Barrientos.
- Eric Slezak (Obs. de la Cote d'Azur, France) visited H. Quintana.
- Howard Yee (University of Toronto, Canada) visited F. Barrientos.

Visitors and astronomers on observing trips fuel the DAA Colloquium program. More than fifty talks took place during this period, some of them jointly organized with ESO/Vitacura and the Astronomy Department of Universidad de Chile (there is a list in our web page).

5 Specially Funded Programs

In addition to the standard programs supported by CONICYT, Andes Foundation, or the Pontificia Universidad Católica on an individual basis, the DAA currently administers some special programs with more specific goals and longer time scale.

5.1 Princeton University–PUC Program

This is a long term program funded by Fundación Andes, Chile. It provided the seed funding (10^6 US$) that prompted the creation and growth of the DAA starting from 1998. The program established a set of activities for the DAA to carry on with the support of

Princeton University Department of Astrophysical Sciences faculty. They included hiring of new DAA professors, funding of joint postdoctoral positions, joint organizing of conferences, and funding for DAA professors and graduate students to visit PU.

5.2 FONDAP Center for Astrophysics

This is a large institutional grant from CONICYT, Chile, to support research in astronomy and academic exchange between the DAA, the Astronomy Department of Universidad de Chile, and the Astrophysics Group of Universidad de Concepción. It provides funds for research, postdoctoral positions, graduate student fellowships, conferences, and travel.

5.3 αLFA Academic Network

This is a program of cooperation between higher education institutions of the European Union and Latin America approved in July 2003. It is administered by the EuropeAid Co-operation Office of the European Commission. Within the αLFA initiative, the DAA has established a network of academic exchange to support travelling of faculty, postdocs and students with the following institutions: University of Durham (U.K.), Max Plank Institute für Astrophysik (Germany), Universidad de Cataluña (Spain), Observatoire de Toulouse (France), Observatorio de la Universidad de Córdoba and Instituto Argentino de Física del Espacio (Argentina), Universidade de São Paulo (Brazil), Instituto Nacional de Astronomía Óptica y Electrónica (Mexico). D. Minniti is the node coordinator.

6 Facilities

6.1 Office, Computing and Teaching facilities

The DAA occupies $\sim$700 m^2 in the joint building of the Faculties of Physics and Mathematics, located in the San Joaquín Campus of PUC, to the south of downtown Santiago. The building accommodates offices for faculty, postdocs and graduate students, as well as joint computer rooms for undergraduates, conference rooms, including an auditorium seating 100 people, and the Astronomy Department library with $\sim$3,800 astrophysics books and 24 periodical astrophysics publications. Staf members, students and visitors have access to the University library system with close to 290,000 books and hundreds of periodical publications, including 57 titles in different branches of physics. The University supports, in addition, on-line access to all major astrophysics journals. Finally, the DAA hosts (since 1998) the first Latin-American mirror of NASA's Astrophysical Data System (ADS).

The DAA computer system is based on a network of Unix hosts including SUNs, HPs and PC-Linux machines (more than 50 desktops and servers). A special computer room is reserved for undergraduate students (graduate students have machines on their desks). Massive computing tasks are handled by the DAA "Beowulf" cluster, boasting 10 2.4 GHz Xeon processors, 8 GB of RAM and a 1.3 TB hard disk array. The DAA ethernet allows 100/10 Mb/s wired connections and 11 Mb/s controlled wireless access. The outside world is accessed through a 15 Mb/s link, shared with the rest of the University. The DAA system supports all major computer languages, astrophysics and graphics software packages.

The DAA maintains a Teaching Observatory, which is supported by the *Small Telescopes Laboratory*. The goal of the lab is to upgrade the electronics, optics, or mechanical parts of telescopes donated to the DAA for teaching purposes, or otherwise adapt for teaching the commercial telescopes purchased to support undergraduate class work. In addition, the lab develops web based tools to control the telescopes with the goal of allowing remote observing to students of other parts of the country.

The Teaching Observatory has two 40cm, one 30cm and one 20cm telescopes. The smaller ones are portable. Instrumentation includes a CCD camera and a CCD spectrograph, in addition to standard eyepieces and photographic plates or film. The 40cm telescopes are now installed in a temporary lab-dome on campus, but will be moved to the permanent observatory within the coming year.

6.2 Telescopes

Scientists and students from the DAA, and qualifying visitors (see 4), can apply for time at the international observatories installed in Chile. Time is granted in general within a 10% of the time reserved for Chilean institutions, and is administered in different ways by each observatory. During the period reported, proposals where a DAA staff member, postdoc, student or qualifying visitor was the PI obtained: 23n at the ESO 8.2m VLTs, 7n at the 8.0m Gemini South, 19n at the LCO 6.0m Magellan, 10n at CTIO 4.0m Blanco, 2n at ESO 3.6m, 5n at LCO 2.5m du Pont, 4n at CTIO 1.5m, 7n at the 1.5m Danish (La Silla), 7n at the 1.3m Warsaw (LCO) and 6n at the LCO 1.0m Swope telescopes.

7 Academic and public duties

Astronomers of the DAA have to take part on the Faculty and University councils and represent the public interest of Chilean Astronomy within national and multi-national committees. During the period reported, F. Barrientos, A. Clocchiatti, and D. Minniti served as expert consultants for the ESO OPC; D. Minniti served as well as a member of the ESO STC; L. Infante and D. Minniti served as members of AURA/Chile TAC (distributing time at CTIO, Las Campanas and Magellan). L. Infante was a member of Gemini ITAC. H. Quintana served as member representative in AURA, and was appointed to the AURA Nominating Committee. A. Reisenegger served as a member of the FONDECYT Study Group in Physics and Astronomy, which oversees the competition for individual FONDECYT grants. L. Infante, D. Minniti, and H. Quintana served as members of the National Astronomy Committee, advisory of CONICYT.

8 Meetings supported

One of the tasks of the DAA is to support meetings and graduate schools in Chile to foster the development of local professional astronomy. In the period reported, activities organized, sponsored, and/or supported were (name of meeting/school, organizing institution, place and date)

- *Annual Meeting of the Chilean Astronomical Society* (Chilean Society of Astronomy and Astrophysics, Santiago, January 2003).
- *Chilean School of Gravitation and Cosmology* (Pontificia Universidad Católica de Valparaíso, Valparaíso, September 2003).

9 Special Outreach Activities

Astronomers and students at the DAA take part in dozens of outreach events every year (radio, TV, and/or printed press), mainly in reaction to news generated outside the university. A few special activities have been organized or coordinated by the DAA.

G. Hertling (General Coordinator), A. Clocchiatti (Astronomy Academic Coordinator), and H. Quintana (Relativity Academic Coordinator) with the help of D. Minniti and A. Reisenegger, and jointly with F. Claro, R. Benguria, M. Depassier (of the Physics Department) developed a year-long course on physics and astronomy targeting high-school teachers, reporters, and the general public.

M. Gómez supported the PUC *PENTA* initiative, where gifted elementary and high school students in social risk spent the Fridays and Saturdays in campus to develop their intellectual capabilities.

G. Galaz and J.M. Fernández (a senior undergraduate student) coordinated the "Mars Watch" event, providing a campus-wide opportunity to see Mars through a telescope, as it went through its closest approach to Earth in ∼60,000 years. More than a hundred people attended.

10 Scientific Activities 2002/2003

10.1 Extrasolar planets and other dark things

The MACHO Collaboration, including D. Minniti and A. Drake, presented a paper with the results of a search for isolated black holes in the disk of the Milky Way. Six candidate black holes were identified based on the parallax fits to the microlensing light curves, and correspond to stellar mass black holes.

M.Sc. student J. Gallardo and D. Minniti obtained Magellan optical-near IR spectra and IR photometry of candidate transit extrasolar planets from the OGLE search database. Out of the ∼100 transits present at the time, they were able to reject roughly 1/2, thus refining the list of good extrasolar planets candidates.

A. Drake has been working on the detection and characterizations of photometric planetary transits in the MACHO project database in collaboration with K. Cook (LLNL/IGPP). Eleven candidate planetary transit events were discovered. Drake has also analysed the OGLE group planetary transist candidates and discovered that half of these events could be ruled out because of the clear presence of ellipsiodal modulations due to stellar-mass secondaries.

Drake and Cook have searched for stellar transits by baryonic dark matter in the form of cold compact dark clouds toward the Magellanic clouds and the Galactic bulge. Fifty million light curves in the MACHO project were searched for dark cloud transits and no cloud transits were discovered. This result strongly suggests that dark clouds do not make up a significant amount of matter towards the Galactic disk or the Magellanic Clouds. A search for dark matter in the form of halo white dwarfs stars has also begun with a series of observations with the Mosaic-II imager on the CTIO 4m.

The Galactic Exoplanet Survey Telescope (GEST) is a Discovery type mission space telescope proposed to NASA by D. Bennett, D. Minniti and collaborators. In a paper published this year, these authors describe the mission, which would observe a 2 square degree field in the Galactic bulge to search for extra-solar planets using a gravitational lensing technique, and would allow for the first time to find large numbers of low-mass planets down to the mass of Mars.

G. Mallen (then at Princeton U.), with D. Minniti and collaborators, started a search for planetary transits across main-sequence stars, the EXPLORE Project. Their first papers presented the technique, data reduction and analysis, and discuss the discovered candidates.

10.2 Stars and sub-galactic stellar systems

J. Borissova and V.D. Ivanov (ESO, Germany), D. Minniti, A. Stephens, D. Geisler (U. de Concepcion, Chile), F. Bresolin (IfA, Honolulu) and P. Pessev (Sofia University, Bulgaria) are searching new Milky Way star clusters in the 2MASS Point Source Catalog. All-sky infrared surveys allow to study the obscured cluster population in the disk of the Milky Way that is hidden by severe dust extinction (10-20 mag). A major drive for such studies is the discovery of new globular clusters and massive Arches-like young clusters. Using fully automated density variation techniques, 14 new IR cluster candidates are found. Follow up observations of the candidates close to the Galactic center have been done at the 4.2m INGRID, 4m Blanco and 6.5 Magellan telescopes.

M. Catelan and collaborators have continued their studies of variable stars. They have been searching for variable stars in globular clusters, focusing primarily at the RR Lyrae and Population II Cepheids. Undergraduate student R. Salinas is using data obtained by J. Borissova and J. M. Fernández with the Danish 1.54m telescope to study the variable star population in globular clusters of the Sagittarius dSph galaxy, namely: Arp 2, NGC 5634, Terzan 8, and Palomar 12. M.Sc. student R. Contreras is studying the variable star population in M62, using data obtained by J. Borissova and R. Contreras with the CTIO 1.3m telescope and the LCO

Warsaw/OGLE 1.3m telescope.

Catelan and Borissova have continued their systematic study of globulars showing peculiar horizontal branch morphologies. Images of the globular clusters NGC 1851 and NGC 2808, which have bimodal horizontal branches, obtained by J. Borissova, M. Catelan, T. M. Corwin, and J. M. Fernández with the Danish 1.54m telescope, are being used to search for variable stars.

Catelan, J. Borissova, T. M. Corwin (UNC at Charlotte), and H. A. Smith (Michigan State U.), have used data obtained by J. Borissova, M. Catelan, R. Kurtev with the 2m telescope of the Bulgarian Rozhen Observatory, to produce the first high-quality CCD light curves for variable stars in the key Oosterhoff type II globular cluster M15. With collaborators G. Clementini (Bologna) and H. A. Smith, a systematic search for variable stars in the Fornax dSph globular clusters is also being conducted, using the Magellan 6.5m and CTIO 4m telescopes, with the chief goal of reliably establishing their Oosterhoff types.

M. Catelan's FONDECYT Research Assistant C. Navarro and A. Stephens, are utilizing the 2MASS database to compute ellipticities of Galactic globular clusters that are free from differential extinction effects. In addition, M. Catelan's team is currently measuring the rotation velocities of the flattened globular cluster in the WLM galaxy, which will help decide whether globular cluster ellipticities can be due to rotation. The team is also working to implement a functional stellar evolution code at PUC.

M. Catelan has found, by computing theoretical simulations and comparing with the available data for the globular cluster M3, that the period distributions of RR Lyrae stars in Galactic globular clusters may be fundamentally inconsistent with our current understanding of the interplay between stellar pulsation and evolution, thus implying a breakdown of the canonical evolution/pulsation framework for these stars. He has suggested that stellar evolution may become slower when RR Lyrae stars change mode from fundamental to first-overtone (and vice-versa). His undergraduate student C. van Rysselberghe is extending Catelan's theoretical analysis to the RR Lyrae stars in more metal-poor globular clusters. With B. J. Pritzl (NOAO), H. A. Smith, P. B. Stetson (DAO), A. V. Sweigart (NASA/GSFC), A. Layden (Bowling Green), and R. M. Rich (UCLA), M. Catelan has used HST snapshot data to search for variable stars in the central regions of NGC 6441. A total of 57 variables was found, including 38 RR Lyrae, 6 Population II Cepheids, and 12 long-period variables. An I-band period-luminosity relation for RR Lyrae stars was provided, and the period-luminosity relation for Pop. II Cepheids was reexamined. With B. J. Pritzl and H. A. Smith, M. Catelan's systematic search for variable stars in metal-rich is ongoing, now focusing at NGC 6304 and NGC 6569, with data from the CTIO-Yalo telescope.

A. Drake has carried out a search of the USNO-A catalog in order to discover stellar clusters within the Galaxy which may have been missed by past surveys. Many hundreds of known globular and galactic clusters were recovered. Several new open clusters were discovered while a dozen more require additional follow-up.

As a part of his dissertation work, M. Gómez (with T. Richtler, U. de Concepción, Chile), have been working on the Globular Cluster System of NGC 4374, a giant elliptical galaxy in Virgo, trying to see if its high rate of SNe Ia is due to the presence of an intermediate age population. They want to confirm that the low specific frequency of clusters is due to too much light and not too few clusters, and the suspected alternative explanation is that NGC 4374 is not an E galaxy, but an S0 one seen nearly face on.

Andrew Stephens and his collaborators have been studying the stellar populations in two nearby Local Group galaxies, M31 and M33. Using the Gemini North telescope and adaptive optics, they observed the central 22" of M33. Based on the slope of the infrared giant branch they estimate the mean metallicity to be -0.26, and from the luminosities of the most luminous stars, they estimate that there were two bursts of star formation 2 and 0.5 Gyr ago. They also found that the stellar luminosity function not only has a different bright end cutoff, but also a significantly different slope than that of the Galactic bulge, and they suggest that this difference is due to the young stellar component in M33. Using the Hubble Space Telescope and the infrared camera NICMOS, they have also analyzed nine fields in M31 with galactocentric distances ranging from 2' to 20'. These infrared observations provide some of the highest resolution measurements to date, and place some of the tightest constraints on the maximum luminosities of stars in the bulge of M31. The measured peak luminosity of the asymptotic branch is significantly fainter than previously claimed. Using simulations they have shown that previous measurements were affected by image blending. They thus concluded that the red giant branch of the bulge of M31 is not measurably different from that of the Milky Way's bulge.

Clocchiatti and M.Sc. student J. Gallardo, continued to study the very late light curve of SN 1994I based on HST WFPC2 observations, with the goal of shedding light on the issue of positron trapping in the ejecta. The late light curve indicates that energy input from γ-rays originating in the ^{56}Co to ^{56}Fe decay is insufficient to provide the observed flux, while full trapping of positrons will give energy in excess of that observed.

A. Reisenegger's concentrated on some aspects of the evolution of neutron stars. He and his M.Sc. student A. Bonačić extended a scenario proposed by Wagoner (2002) for the evolution of neutron stars in low-mass x-ray binaries (LMXBs) under the effect of r-modes made unstable by the emission of gravitational waves in the so-called Chandrasekhar-Friedman-Schutz instability. They showed that the instability would still be active in the millisecond pulsars (MSPs) descending from these binaries, whose spin-down rates and surface temperatures can then be used to constrain the strength of the emitted gravitational waves, their possible effect on

LMXBs, and the interior physics of the neutron star, in particular the possible presence of hyperons and their superfluid pairing gaps.

Reisenegger and undergraduate students M. Taghizadeh and R. Fernández are evaluating the expected temperatures of MSPs under a different internal heating mechanism, "rotochemical heating", due to slightly non-equilibrium composition changes occurring as the neutron star spins down. Preliminary, Newtonian models with non-interacting fermions worked out as the students' undergraduate theses are now being extended by Fernández and Reisenegger to relativistic models with realistic equations of state. Optical observations of MSPs with the VLT involving Reisenegger and other DAA members together with international collaborators yielded an upper limit and a possible (though perhaps unlikely) detection, unfortunately too bright to give meaningful constraints on the internal heating processes mentioned above.

Under the guidance of Reisenegger and Univ. F. Santa María professors O. Espinosa and C. Dib, undergraduate student Mario Riquelme worked out the effect of a strong magnetic field (as expected in "magnetars") on weak interactions ("Urca processes") in degenerate matter. He found that, even if many Landau levels are populated by protons and electrons, strong oscillations in the rates can occur when the magnetic field (or another physical parameter) is changed. However, as realistic neutron stars are likely to cover a range of parameters, these oscillations probably average out. Thus, the global neutrino luminosity is likely to be similar to its value in the zero-field limit.

10.3 Nearby Galaxies

J. Borissova, D. Minniti, M. Rejkuba (ESO, Germany) D. Alves (Columbia University, USA), K. H. Cook (LLNL) and K. C. Freeman (MSSSO, Australia) studied the properties of RR Lyrae stars in the inner regions of the LMC. Intermediate resolution spectra and infrared images were obtained with FORS1 at the ESO VLT and with SOFI at the ESO NTT. Using radial velocities a true LMC RR Lyrae velocity dispersion of $\sigma = 353$ km/s is obtained. This is higher than the velocity dispersion of any other LMC population, and the first empirical evidence of a kinematically hot metal-poor halo in the LMC.

Borissova with M. Rosado and L. Georgiev (UNAM, Mexico) and R. Kurtev (Sofia U., Bulgaria) have studied the link between star formation and interstellar medium in a set of irregular galaxies of the Local Group. They use scanning Fabry-Perot interferometry to study the kinematics of bubbles and superbubbles, and U,B,V photometry to constrain the stellar content of the bubbles and the distribution of massive stars.

A. Clocchiatti, P. Lagos, and P. Garnavich (Notre Dame U.), continued to prepare the data set for a comparative study of SN parent galaxies at low and high z. Using Magellan and the ESO 3.6m telescope they observed integrated optical/near IR spectra of parent galaxies of SNe in the nearby sample, to measure metallicity, age, and global ionization and compare with those of the parent galaxies of the distant sample.

Drake, Cook, Cieslinski (DAIN) and Diaz (IAUS) have carried out an analysis of light curves in the MACHO project database in order to detect cataclysmic variables stars. More than 30 new CV stars have been discovered. Drake, Nikolaev (IGPP), Keller (IGPP), Cook (IGPP), Dalal (IAS), Welch (McMaster), Kanbur (UMASS) have worked on a combined analysis of 2MASS and MACHO data to determine the fundamental structure of the LMC using Cepheid stars.

D. Minniti and collaborators combined excellent quality images obtained with the VLT in BVRI with published deep Chandra X-ray observations. They obtained optical identification of X-ray sources in Centaurus A, including the discovery of new globular clusters.

B. Dirsch carried out a massive spectroscopic survey of NGC1399 globular clusters together with D. Minniti and collaborators. They presented a radial velocity catalog for 500 globular clusters, and a kinematical study of this cD galaxy.

M. Rejkuba with Minniti and collaborators obtained deep VLT optical and IR images of the halo of the giant galaxy NGC5128. Comparing the photometry with theoretical isochrones, they found a significant intermediate-age population. Based on 20 epochs of VLT IR images, they discovered 1700 variable stars, mostly Miras and LPVs. In addition, the distance to this galaxy was measured using three different indicators (RGB Tip, Miras P-L relation, and GC LF). During a spectroscopic follow-up of NGC5128 globular clusters at the Magellan I telescope on May 2002, Minniti and Rejkuba discovered the first extragalactic globular cluster planetary nebula.

S. Piatek and collaborators, including Minniti, started a program to obtain deep images of dwarf galaxies satellites of the Milky Way with the Hubble Space Telescope, in order to measure their proper motions. The first results on the proper motion of the Fornax galaxy were published.

M. Kissler-Patig (ESO, Germany), Minniti and collaborators started a near-IR photometric survey of globular cluster systems in giant elliptical galaxies. The first two papers on NGC4478, M87, and on NGC3115, NGC4365, allowed them to compare the different populations of globular clusters of these galaxies, attacking the age-metallicity problem.

D. Alves, D. Minniti and collaborators used accurate near-IR photometry obtained with SOFI at the ESO New Technology Telescope to measure the mean K-band magnitude of clump giants in the Large Magellanic Clouds. They published an accurate distance to the LMC based on the comparison with the Hipparcos clump giants.

The MACHO Collaboration, including D. Minniti and A. Drake, discovered three eclipsing Cepheid variables in the Large Magellanic Clouds. These are the first such objects found. They will allow studies of stellar evolution and to accurately measure stellar parameters

using future follow-up spectroscopy.

10.4 Galaxies and larger structures

F. Barrientos, M. Gladders (OCIW), H. Yee (U Toronto), L. Infante, P. Hall (PUC/PRINCETON) and E. Ellingson (U Colorado) have continued studying the properties of cluster galaxies and galaxy clusters. Some of the first results of the Red-Sequence Cluster Survey (RCS) have been presented, particularly the discovery of many new galaxy clusters up to redshift 1, 8 of them with strong lensing. The high number of strong lensing systems and their redshift distribution is inconsistent with current models, implying most probably the need for a more detailed treatment of the individual clusters of galaxies.

F. Barrientos and S. Lilly studied the photometric properties of cluster E/S0 galaxies at z=0.45, finding that the small scatter in their optical-IR colors and their color evolution is consistent with star formation at epochs earlier than z=1. Barrientos and D. Stern (CALTECH), P. Hall (PUC/PRINCETON), A. Bunker (Cambrigde U.), R. Elston (U. of Florida), M. Ledlow (GEMINI), S. Reines (U. of Florida) and J. Willis (U. of Victoria), tested the multiobject spectroscopic capabilities of FLAMINGOS on Gemini South, presenting IR spectra for one the most distant QSO known, SDSSJ083643.85+005453.3.

G. Galaz continued his work on low surface brightness (LSB) galaxies, focusing on the properties of their old stellar populations as seen in the near-IR. Galaz obtained high S/N Magellan spectra of selected LSB galaxies to measure the metallicity of the ellusive old bulge stellar population from their absorption lines. New spectrophotometric models including dust absorption are being used to model the optical properties of these LSB galaxies.

G. Galaz was also collaborating with the ESO Scultor Survey (ESS), obtaining final results on the luminosity function as a function of spectral type and on the number density of galaxies as a function of type.

Giovanna Temporin and Galaz has investigated the properties of interacting pairs of galaxies, using optical, near-IR and spectroscopic data.

L. Infante has collaborated with the Sloan Consortium (SDSS) identifying close pairs of galaxies on $\sim$2000 deg^2 of commissioning imaging data and DR1. The angular correlation function of galaxy pairs was determined and found to be stronger than that of single galaxies. These results agree with the global richness dependence of the correlation functions of galaxy systems.

Infante, Galaz, the SDSS group and students at PUC, have measured redshifts for nearly 1000 galaxies drawn from the SDSS catalog. They study the redshift distribution of galaxies and galaxy pairs, derived photometric redshifts, study PCA morphology and the galaxy merger rate.

L. Infante, M. Hilker (U. of Bonn, Germany) and S. Mieske, are carrying out a large study of the properties of dwarf galaxies in clusters, focusing now on the Fornax cluster. The relation between the Ultra Compact Objects (UCOs) recently discovered and the brightest globular clusters associated with the central galaxy NGC 1399 has been investigated. Eight are new members, four were known. Their magnitude distribution supports a smooth transition between the faint UCOs and the bright globular clusters. Also, $\sim$ 70 very faint dwarf galaxies, dSph candidates, were discovered. They follow the same magnitude-surface brightness relation as their counterparts in the Local Group, and even extend it to fainter limits. The faint-end slope of the luminosity function of the early-type dwarfs is flat ($\alpha = -1.1 \pm 0.1$). The potential of the Surface Brightness Fluctuations (SBF) as a method to determine the membership of dwarf galaxies in nearby clusters has been studied, as it will permit the study of the faint tail of the luminosity function. Infante, the ACS Science team, Mieske and PUC students are studying Gobular Clusters, UCDs and Dwarf galaxies in the cluster A1689. They identified 9 new UCDs and measured the faint end slope of the galaxy luminosity funtion (-1.4).

E. LeFlock and collaborators, with Minniti, obtained very deep IR images of twanty known gamma-ray bursts. They were able to identify the host galaxies, and assess their properties. It turned out that these GRB hosts are puny galaxies at low or intermediate redshifts, not fully assembled into large disk galaxies like the Milky Way.

10.5 Large Scale Structure

H. Quintana worked in collaboration with members of several European centers in the coordination and preparation of observations for the XMM-LSS project. Two seasons of observations with the XMM Newton satellite have produced over 100 cluster candidates. 17 of them, spanning the redshift range z= 0.3 - 1.0, were spectroscopically confirmed with VLT and Magellan telescopes, and further observations are coming through the pipeline now. Quintana has also continued working in the 160 sq. deg. ROSAT survey and in the new ROSAT 400 sq. deg. survey. G. Galaz also worked with the spectroscopy sub team of the XMM-LSS collaboration, which is in charge of acquisition, reduction, and coordination of the spectroscopic database.

H. Quintana and A. Reisenegger lead the local part of an international effort in the study of the Shapley Supercluster, the largest agglomeration of clusters of galaxies in the local Universe ($z < 0.1$). The redshift catalog of the relevant area of the sky has now been extended to a total of near 9000 velocity measurements, corresponding to more than 7000 different galaxies. A precise photometric catalog of the same area is being constructed, while a completeness analysis of the redshift catalog by comparison with previous photometric catalogs is also under way. Simulations extracted from the Virgo Consortium results are being used to study the dynamics of superclusters, in order to assess the validity of dynamical models used previously in the analysis of Shapley data.

10.6 Quasars

L. Infante, Moles and Varela tested the hypothesis whether high redshift QSOs would preferentially appear in small groups or pairs, and if they are associated with massive, young clusters. A photometric search for $Ly\alpha$ emitters on scales $< 10h^{-1}$ Mpc was done, in the fields of a sample of 47 $z \approx 3$ known QSOs. Wide and narrow band filter color-magnitude diagrams were generated for each of the $6'.6 \times 6'.6$ fields. A total of 13 non resolved objects with a significant color excess were detected as QSO candidates at a redshift similar to that of the target. Follow-up spectroscopic observations have shown that 5, i.e., about 40% of the candidates, are QSOs at the same redshift of the target; 4 are QSOs at different redshift (two of them are probably a lensed pair at z = 1.47); 2 candidates are unresolved HII galaxies at z$\sim$0.3; one unclassified and one candidate turned out to be CCD flaws. These data indicate that at least 10% of the QSOs at z$\sim$3 do have companions. A similar search for Ly_α emitters in the field 12 of z=2 quasars was carried out. UV narrow and broad band observations were performed with the CTIO 4m MOSAIC camera. A number of candidates were found. Follow up spectroscopic observations are planned.

Infante, with Silverman, Green, Kim, Wilkes, Cameron, Morris, Dosaj, Smith, Mathur and Jannuzi, presented the discovery of a z=4.93, X-Ray-selected Quasar by the Chandra Multiwavelength Project (ChaMP). This object is the most distant X-ray-selected quasar published.

F. Courbin, D. Minniti and collaborators analyzed the spectrum of the QSO HE 1503+0228, at $z = 0.135$. They performed an on-axis resolved spectroscopic study of this source, using spectral deconvolution techniques to separate the spectrum of the QSO from that of its host galaxy, and being able to measure a redshift of the host.

The MACHO Collaboration, including D. Minniti and A. Drake discovered 38 quasars behind the Large Magellanic Cloud and 9 quasars behind the Small Magellanic Cloud. Their search for background QSOs in these dense fields was based on optical variability, and all the candidates have been spectroscopically confirmed.

10.7 Cosmology

A. Clocchiatti continued to support the research of the ESSENCE project (www.ctio.noao.edu/$\sim$essence). He worked on one of the search campaigns at CTIO and held a run at Magellan to do follow-up photometry and spectra of the discovered candidates. In addition, he coordinated the infrared follow-up observations from VLT/ISAAC.

A. Clocchiatti and P. Challis (Harvard U.) also continued the analysis of one of the 1999 campaigns of the High Z SN Search Team. They reduced, matched, and subtracted ground-based and HST images of five Type Ia SNe, all of them near a redshift of 0.5, measured and K-corrected the photometry, and applied the Δm_{15} method to determine reddening corrected intrinsic brightness and, hence, distance moduli. The results are consistent with the distant SNe being too dim in comparison with the local ones, even for the predicted distances of an empty universe, an almost certain indication that the expansion of the Universe is accelerating.

As a spin-off of the research with the High Z SN Search Team, undergraduate student J.L. Prieto and Clocchiatti studied the possibility that the dimness of the distant SNe is related with the photometric technique that both the ESSENCE/High Z SN Search Team and the SN Cosmology Project use. They both take images of the field without the SN, match the PSFs, and subtract, to do photometry on the residuals. Prieto and Clocchiatti took a different approach to estimate the sky background underneath the distant SNe by using the Magain, Courbin & Sohy deconvolution technique. The results show intriguing (small) systematic differences in photometry (now under study) but still make the distant SNe too dim for their redshift, even in an empty universe, supporting the detection of an acceleration.

11 Books written & Edited

- **H. Quintana** finished the second volume of "Espacio, Tiempo y Universo", a course on relativity for non-science undergraduate students, and submitted it to PUC Press.
- F. Courbin & **D. Minniti** edited "Gravitational Lensing: An Astrophysical Tool", 2002, Springer-Verlag (Heidelberg), ISBN 3-540-44355-X
- D. Geisler, E. Grebel, & **D. Minniti** edited the IAU Symp. 207 on "Globular Clusters in Galaxies", 2002, ASP (San Francisco), ISBN 1-58381-115-X

12 Reviews

M. Catelan presented the invited review *Variable Stars in Globular Clusters and Nearby Galaxies* at IAU Colloquium 193, in Christchurch, New Zealand. In his paper, Catelan pointed out that the Oosterhoff dichotomy, which is present among Galactic globular clusters and field halo stars, but not among the Milky Way satellite galaxies, may pose the strongest constraints so far on the extent to which the bulk of the Galactic halo may have formed from the accretion of (dSph-like) protogalactic fragments. Catelan also presented the first theoretical calibration of the RR Lyrae period-luminosity relation in I, J, H, K which fully takes evolutionary effects into account. He noted, in addition, that widely employed recipes for the determination of the masses and luminosities of first-overtone RR Lyrae stars, based on Fourier decomposition of their light curves, are in sharp conflict with the basic period-mean density relation of stellar pulsation theory.

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