Max-Planck-Institut für Astronomie

Heidelberg, Germany

This report covers the period from January 1 to December 31, 2001 and is an abbreviation of the more detailed German version published in Mitt. Astron. Ges., 2001.

The year 2001 saw the achievement of several important milestones regarding the long-term development of the Institute. First of all, naming Prof. T. Henning (Jena) as successor to Prof. Beckwith re-completed the board of directors at MPIA. Henning's goals in the scientific field of star and planet formation as well as in the instrumental field of interferometry and adaptive optics promise to keep up or establish a leading role of the Institute in these fields. So, together with the manifold extragalactic research activities at MPIA, the Institute's excellent facilities for near-infrared observations from the ground as well as from space can be utilized optimally.

Prof. S. Beckwith (STScI) and Prof. R. Rebolo (IAC) could be attracted as nonresident scientific members. R. Ragazzoni (Acetri/MPIA), winner of the Wolfgang-Paul Prize of the Humboldt-Stiftung (the most highly remunerated German science prize) joined the Institute to work on adaptive optics, e.g. for the LBT.

J. Staude received the Bruno-H.-Bürgel prize of the Astronomische Gesellschaft for his 20 years of service for the journal ‘‘Sterne und Weltraum’’.

1 STAFF

Heidelberg

Directors: Rix, Henning (from 1.11.2001).

Scientific staff: Ábrahám (until 22.4.2001), Andersen (from 15.11.2001), Bailer-Jones, Beetz, Birkle, Burkert, Dehnen, Feldt, Fried, Graser, Grebel, Haas, Héraudeau, T. Herbst, Hotzel (from 1.7.2001), Jester (from 15.9.2001), Hippelein, Hofferbert, Klaas, Kümmel (until 2.12.2001), Leinert, Lemke, Lenzen, Ligori, Marien, Meisenheimer, Mundt, Naab, Neckel, Odenkirchen, Ollivier (until 28.8.2001), Phleps (from 1.10.2001) Röser, Slyz (until 30.6.2001), Staude, Stickel, Tóth (from 15.10.2001), Vavrek (from 1.9.2001), Wolf, Wilke.

PhD students: Bertschik (from 1.3.2001), Büchler (from 1.7.2001), Brunner (from 1.9.2001), Dib, Geyer, Harbeck, Hartung, Heitsch (until 30.6.2001), Hempel (from 1.8.2001), Hetznecker (until 14.3.2001), Hotzel (until 14.4.2001), Jesseit, Jester (until 14.9.2001), Khochfar, Kleinheinrich (until 31.3.2001), Kovács (from 1.11.2001), Kranz, Krause, Krdzalic (until 28.2.2001), Lamm, Lang, Maier, McIntosh (15.1. - 30.6.2001), Mühlbauer, Ofek (29.1. - 4.3.2001), Phleps (until 30.9.2001), Przygodda, Puga, Rudnick (until 14.11.2001), Sarzi (1.7. - 30.11.2001), Schuller (until 14.2.2001), Stolte, Walcher (from 1.11.2001), Weiss, Wetzstein (from 1.2.2001), Ziegler (from 1.10.2001).

Diploma students: Bertschik (until 28.2.2001), Tschamber (from 24.4.), Walcher (until 31.7.2001), Wetzstein (until 31.1.2001), Ziegler (until 30.6.2001), Zimer (from June 2001).

Scholarship holders: Butler (from 15.1.2001), Caldwell (from 26.4.2001), Chesneau (from 1.10.2001), Cretton (until 30.9.2001), Del Burgo, D'Onghia (from 1.12.2001), Heitsch (1.7. - 30.9.2001), Hetznecker (1.9. - 31.10.2001), Kessel (DFG), Klessen (Otto-Hahn-Preis, until 30.9.2001),

Kroupa (until 31.1.2001), Lee (from 1.11.2001), Nelson, Pentericci, Popescu (Otto-Hahn-Preis, until 31.8.2001), Travaglio (until 30.9.2001).

Visiting scientists: Ábrahám/Hungary (July), Avila/ Mexico (November - December), Bodenheimer/ USA (December), Böker/USA (May), Ciecielag/Poland (August - September), Devriendt/France (March - April), Dodt/ Germany (June), Dong/USA (June - July), Gallagher/USA (June - August), Gupta/India (November), B. Herbst/USA (June), Hiroshita/Japan (October), Holtzman/USA (May), Hozumi/ Japan (May), Ionita/USA (August - September),

Kiss/Hungary (January, September), Klapp/USA (December), Lin/USA (April - May), Looze/USA (June - August), MacLow/USA (July), Makarova/Russia (November), Mellema/Netherlands (May - June), Mochizuki/Japan (May), Morel/France (April - December), Morgan/USA (June - July), O'Dell/USA (January - March), Ofek/Israel (January - March, June - August), Sanchez/Mexico (November - December), Schechter/USA (June - August), Shields/USA (July - August), Smith/UK (September), Steinmetz/Germany (May - June), Tóth/Hungary (June - August), Vitvitska/Russia (June - August), Zuther/ Germany (September).

Regular international meetings and events were held at the Institute throughout the year; these were attended by other guests who are not listed here individually.

2 CALAR ALTO OBSERVATORY

Local directors: Gredel, Vives.

Astronomy, Coordination: Thiele, Prada, Frahm.

Observing time with the Institute's telescopes was distributed in 2001 as shown in the following table: (columns 2 to 5: number of allocated nights; RDS: German institutes other than MPIA; Sp: Spanish institutes; EX: institutes from other countries)

TABLE 1.

Telescope	RDS	MPIA	Sp	Ex
3.5m	134.6	46.6	32.5	60.3
2.2m	208	36	41	78
1.23m	254.2	42.2	40.2	26.4

2.1 Weather Statistics

The year 2001 was characterized by abnormally bad weather during spring and fall time. There was a total of 178 clear nights with six or more hours of observation time, corresponding to a total of 1731 hours of observation time. The number of photometric nights was 81.

3 TELESCOPES

3.1 The 3.5-m Telescope

Upgrade of the Control System

Work on the new control system is not yet finished. Only the dome control system was redesigned and put successfully into operation in summer 2001. (R. Wolf, Gredel, Grimm, Müller, Zimmermann)

Dome Ventilation

During the summer months, additional ventilation holes were cut into the 3.5-m dome by DSD in order to improve the dome seeing. The openings are located opposite the slit between the arched girders, extending almost to the height of the crane way, and can be closed using louvered shutters.

4 INSTRUMENTAL DEVELOPMENTS, COMPUTING FACILITIES

4.1 Instruments for Calar Alto

4.1.1 LAICA: Large Area Imager for Calar Alto

In April, the new LAICA wide field camera was used for the first time at the telescope. As two of the four CCDs had been delivered only shortly before the tests, optimizing was not possible yet. The readout turned out to be not free of trouble and will have to be improved considerably. Two of the 16 quadrants did not provide a signal; the failure could be attributed to a faulty pre-amplifier and a crack in the substrate, respectively. Nevertheless, it became clear that there are no unsolvable problems with the camera, as far as can be judged after tests made under mediocre conditions. (Fried, Marien, Grimm, Klein, Unser, Briegel, Zimmermann)

4.1.2 Omega 2000: a New Wide Field Near-infrared Camera for the 3.5-m Telescope on Calar Alto

Meanwhile, all major parts of this instrument, which has been described in detail in the Annual Report 2000, were manufactured or delivered. However, integration is not completed yet so that first use at the telescope cannot take place in 2002 as planned originally. At the moment, first light is scheduled for early 2003. (Bailer-Jones, Bizenberger et al.)

4.1.3 CCD Systems

Early this year, the last two CCD 485 for the LAICA project, Lock #6 and Lock #7, were delivered by BAE (formerly Lockheed). The quality of the CCDs meets the specifications and is comparable to Lock #4 and Lock #5, except for the fact that one quadrant of Lock #6 is affected by output amplifier glow. The detectors Lock #4, Lock #5, Lock #6, and Lock #7 have been chosen as science-grade CCDs for LAICA. Late in April, first tests of LAICA were carried out on Calar Alto, revealing the following problems: The signals of two of the quadrants only consisted of noise, the CCDs' entrance windows misted over with dew during the measurements at the telescope, one channel of the guider system failed completely, and the readout electronics of LAICA was working unreliably and showed a noise level that is too high.

Unfortunately, later at MPIA the failure of the two quadrants turned out to be caused by the CCD detectors: Lock #5 was showing a crack in the substrate, as Lock #3 had done before (see Annual Report 2000), and as to Lock #7, an output amplifier on the CCD failed completely. Luckily, Lock #5 could also be repaired later by the manufacturer. The failure of Lock #7 could have been caused by a plug problem when the dewar was being connected to the readout electronics. The failure of two CCDs due to cracks in the substrate led to several mechanical changes in the CCD mounting, by which the stresses on the detectors could be reduced, particularly during the cooling process. In future, the misting over of the dewar windows will be avoided by flushing them with gaseous nitrogen from the dewar tank. Late in November, cooling tests showed that the repaired quadrant of Lock #3 breaks down at temperatures below -80°C. For scheduling reasons, however, another immediate repair was not possible. By the end of the year, LAICA was rendered completely ready for operation.

In the year under report, the participation of MPIA in the DIVA project was extended beyond consultation activities. In a laboratory study, the CCD detectors destined for the mission, which are manufactured by Marconi, are to be examined in more detail. Special attention will be paid to the issues of heat input and dark current as well as the effects of extraterrestrial radiation load. The study will be carried out partially in parallel at the Sternwarte der Universität Bonn and at MPIA. For this purpose, four test detectors were ordered within the frame of a DFG proposal. They will be delivered early 2002. At MPIA, components needed for the study, such as a cryostat and TDI light source, were prepared.

The Thüringer Landessternwarte Tautenburg plans to equip the Schmidt telescope with a 4K $\times$ 4K-CCD of type 486 manufactured by BAE. The CCD 486 is the successor model of the CCDs used in LAICA. Our experience with these detectors is to be included into the construction of a cryostat and the operation of the system. As a first step, the flatness of the detector was measured at MPIA in December using a laser-optic measuring system. (Marien)

4.1.4 DIMM: Differential Image Motion Monitor

In March 2001, the Differential Image Motion Monitor was put into regular operation. The instrument performs absolute measurements of the seeing at 20-second intervals. Measurements during the summer of 2001 showed the average seeing at Calar Alto to be less than 1 arc second. (Gredel, Thiele)

4.2 LBT and Instrumentation

4.2.1 LUCIFER: the Multimode Infrared Camera for the LBT

After some failures, the IRG2-blanks for the optics could be manufactured with sufficient quality. The concept of the cryogenic structure with all movable parts was completed. The cryostat itself was completed to the point that the tank can presumably be ordered in March 2002. Single parts such as the ADCs of the readout electronics, the detector multiplexer, and the engineering array were already delivered; the science array will probably be delivered in the middle of 2002. (Bizenberger, Laun, Lenzen, Grimm, Rohloff)

4.2.2 LINC: the Diffraction-limited Camera for the LBT with an Aperture of 23 m

Conceptual development of the diffraction-limited wide-field camera (diameter of the field of view = 1') for the LBT proceeded under the leadership of T. Herbst. The actual beam-combiner is being designed and constructed at MPIA, while the cryostat and the tip- tilt-sensor are contributed by the University of Cologne (Prof. Eckart). The adaptive optics system is being developed in Arcetri by P. Salinari, together with R. Ragazzoni (MPIA/Arcetri). In November 2001, a first concept design review has taken place; the final concept will be drawn up by the middle of 2002. LINC will be developed in two stages. First, diffraction-limit is planned to be achieved using only one natural guide star; in a second stage (NIRVANA), correction of the wave front at shorter wavelengths ($< 1\mu$ m) will be accomplished using multiconjugate adaptive optics (MCAO) .

4.3 Instruments for Other Observatories

4.3.1 CONICA: the High Resolution Infrared Camera for the VLT

In March 2001, CONICA was combined with the NAOS adaptive optics systems in Meudon. There, a team from MPIA accomplished the professional installation of the wiring, the cooling water supply, the CCD cooling, and the cryostat itself into the Nasmyth- platform and the original corotator, which were erected in a laboratory in Meudon. For another six months, the total NAOS-CONICA system was tested thoroughly. Final optimizations were carried out, and in October, the instrument finally passed the review in Europe. After transport by aircraft to Santiago and subsequent transport to Paranal by truck, the total instrument was installed in November into the Nasmyth-platform of UT4.

With the international press showing great interest, the system was successfully used for the first time at the telescope (see press release of ESO, November 3, 2001). (Becker, Böhm, Hartung, Laun, Lenzen, Meixner, Münch, Rohloff, Storz, Wagner)

4.3.2 MIDI: a Mid-infrared Interferometric Instrument for the VLT

Project management: Graser, Leinert

On March 1, 2001, the final design review for the optics, mechanics, and electronics of the MIDI instrument was formally declared complete by ESO, and on November 17, 2001, the same took place for the software. Simultaneously, construction and testing of the instrument proceeded in the laboratory in Heidelberg. On May 21, the partner institute ASTRON in Dwingeloo delivered the central piece of the device, the ‘‘cold optics’’, which then was adjusted optically and gradually fine-tuned with the mechanics at MPIA. In November and December, first interferometric measurements could be made using an artificial star set up in the laboratory, although this could not yet be done in the automatic operation mode planned for the telescope. In the course of the year, the MIDI ‘‘science group’’ outlined observing programs for the 30 nights of guaranteed observing time at the 8-m telescope of the VLTI. The document containing object lists and abstracts of these programs can be found on the MIDI web page of the Institute. Commissioning of the instrument at the VLTI interferometer on Paranal is planned for late 2002.

Sub-system development status:

The detector readout electronics were tested and upgraded using the engineering- grade detector (Raytheon SiAs, 240 × 320 pixel) housed in a test dewar. After that, the electronics were used to operate the final detector in the MIDI dewar. The planned operation of the detector, including synchronization with the MIDI intrinsic delay line, was possible with the readout noise aimed at of less than 1000 electrons, but only with a readout time of 11 ms (instead of the required 5 ms) for the entire array and not with the desired flexibility. Therefore a new version of the readout electronics was put into operation by the end of the year which is expected to remedy the restrictions just mentioned by doubling the capacity of the data link and using new firmware. (Grimm, Ligori)

Dewar: The final dewar (with a size of 85 cm × 60 cm × 80 cm and a weight of a little over 500 kg) built in the precision engineering workshop at MPIA was put into operation. Temperatures in the region of the inner cold optics and of the detector are 35 K and 5 K respectively, well within the desired range. Functional tests carried out since August confirm the reliability of the entire cryo- vacuum system. (Böhm, Laun, Rohloff)

Control electronics: Temperature sensors, heating, thermostats, reference and end switches were installed within the cryostat and connected. To reduce the tension on the constantan wires, which are only 0.1 mm thick, a special casting technique was developed. The mounting tables of the ‘‘warm optics’’ were modified for operation according to ESO standards. The required emergency switch for the CO_2 laser was installed so that the laser is switched off automatically if the cover is opened or if the flow of cooling water is too low. Two of three planned electronics racks were equipped for the instrument control electronics and supplied with cooling systems. Wiring of the instrument was generally completed. (Wagner)

Optics and optical adjustment: The ‘‘warm optics’’ (delivered by the Kiepenheuer-Institut für Sonnenphysik) that are installed in front of the dewar were equipped with a new foundation plate, the old one not being stiff enough to allow transportation by crane and being prone to vibrations. As for the rest, the ‘‘warm optics’’ proved their efficiency during the tests performed: the feeding of the radiation from the laboratory light sources (laser, black-body radiator) as well as the motion of piezos and motors used for path compensation of the two light beams are working as planned. With the help of ASTRON, the adjustment procedure for the ‘‘cold optics’’ was determined, followed by the rather complicated adjustment at warm temperatures in the laboratory. The goal was to superimpose both interfering light beams with 0.1 mm accuracy and make them parallel with 10″ accuracy; this goal was almost achieved. Final adjustment will take place as soon as the optical behavior of the instrument in the cold is known in sufficient detail. (Annelie Glazenborg-Kluttig (ASTRON), Sebatien Morel (ESO), Frank Przygodda)

Laboratory tests: Meanwhile all planned functions of the instrument can be carried out via a user interface. In November, the expected interference fringes from the light of an artificial star set up in the laboratory were detected for the first time. Contrast between the fringes was 80%, showing the good quality of the optical components and optical adjustment. Satisfyingly, the optical adjustment has changed only insignificantly when the instrument was cooled down. Although not being crucial, background brightness, internal reflections and remaining vibration motions of the image on the detector ($<$ 1 pixel) are in need of improvement. (Chesneau, Jaffe (Leiden), U. Neumann, Przygodda)

Computers and software: Part of the readout software for the new detector readout electronics had to be developed from scratch. In addition, the software interface for the very rapid data transfer between detector workstation and near-real-time-software workstation was defined and implemented as exchange of FITS files via a shared memory. The instrument-control software for driving the electric motors, for the readout of numerous serial interfaces and for rapid variation of the optical path differences by two piezos has been tested successfully during several weeks – primarily during cooled phases. Implementation of the observation software on the so-called instrument workstation was started, and first rudimentary tests of the interaction with the broker of observation blocks, i.e. the command interface of the batch operation lying above, were carried out, including the programming of templates – forms which are to be filled in by the astronomer with parameter values before the data are taken (NEVEC/Leiden). Programming of the off-line data analysis, for laboratory tests as well as for the future scientific operation, is making good progress. (Storz, U. Neumann, Mathar; at NEVEC: de Jong, Bakker, Jaffe (coordinator); at DESPA, Paris-Meudon: Nafati)

4.4 Instrumental Developments and Data processing for Extraterrestrial Research

4.4.1 PRIME - The Primordial Explorer: a NIR-survey Satellite

An industry feasibility study of the PRIME telescope was completed at Kayser- Threde in the middle of the year. The project was submitted by the German side to the consultative panel of the DLR. In an international cooperation of the participating institutes (Johns Hopkins University, Fermi National Accelerator Laboratory, Space Telescope Science Institute, NASA Goddard Space Flight Center, Institut d'Astrophysique de Paris, Swales Aerospace and Space Dynamics Laboratory), the PRIME phase A report was completed and sent to NASA in December. Down-selection is announced by NASA for July 2002. (D. Lemke, R. Lenzen, H.-W. Rix)

4.4.2 ISOPHOT Data Center

During the last year of the ISO post-operative phase, activities in program development and calibration analysis for version 10 of the automatic data analysis (Offline Processing OLP V10.0) were completed. With the processing and analysis of several hundred representative test cases progress compared to the pipeline V9.0 was tested thoroughly. This was the last upgrade of the software used at the ISO data center VILSPA in Spain to create the ISO Legacy Archive.

The new version further improved the photometric calibration accuracy. In addition, validation of chopped measurements made several thousand observations accessible to all observers. Calibration accuracy of the chopped measurements is somewhat less than that of staring-mode observations. In the far infrared, the accuracy of measurements is limited by cirrus confusion. Flatfield accuracy of several thousand raster maps in the staring as well as in the chopped mode was increased to only a few percent by improved deglitching and statistical methods. For multi-aperture measurements, an analysis procedure for relative curves of growth could be implemented.

In the course of a project to measure the extragalactic background radiation, an even more refined calibration of instrumental effects was carried out using all suitable measurements within the mission data base. This includes an improvement of the detector dark signals (instrumental zero point), a refined correction of the signal derivation depending on the readout frequency, and measurement of the fraction of scattered light from the sky within the signal of the internal calibration source (absolute photometric calibration). In addition, the transient behavior of the C100 camera receiver under changing fluxes was characterized. These new calibrations will be incorporated into the ISOPHOT interactive analysis software (PIA) during the first half of 2002.

In the year under report, eight visitors used the ISOPHOT data center in Heidelberg for several days. In February, the ISO Calibration Legacy Conference took place in Villafranca with strong participation of the ISOPHOT data center. At the conference, all calibration steps and the accuracies achieved in the ISO archive were presented. In addition, experts' knowledge was passed on to the scientists and engineers of future missions. By the end of the year, about 190 publications based on ISOPHOT data were published in refereed journals, corresponding to an analysis of about 25% of the scientific data base. In summer, preparations for the five-year long active archive phase started which will follow the post-operative phase; during this archive phase, the remaining 75% of the data will be analyzed and the accuracy and user friendliness of the ISO data base will be increased. (Lemke [ISOPHOT-PI], Ábrahám, del Burgo, Haas, Héraudeau, Hotzel, Kiss, Klaas, Krause, Stickel, Tóth, Wilke)

4.4.3 PACS: the Far-infrared Camera for the HERSCHEL Satellite

For the PACS focal-plane chopper, all mechanical components of the lifetime model (LM) as well as parts for the test sets were manufactured after completion of the design phase at MPIA's workshops and then delivered to Zeiss. In preparation for the durability test, another test model of the chopper was characterized by Zeiss in the cryostat at T $\sim$ 4 K. The CuBe flexural pivots of the chopper, which will be exposed to great load during the rocket launch and the following three-year operation phase, are being qualified for their application in space by additional durability tests at the Fraunhofer-Labor für Betriebsfestigkeit (LBF) at 300 K, that is under a load increased by another factor of 1.3.

As a major contribution to the PACS instrument, MPIA has compiled the specifications of the cryo-harness. This includes the definition of all 1148 cables, together with the cold interface connectors and all of the electrical parameters.

This document is an important basis for the thermal concept of the instrument and will be used for the invitation of tenders for the industrial manufacture of a cable harness qualified for space.

The detector test stand had to be converted generally for additional pre-amplifier types. First tests with a low-stressed Ge:Ga array ($\lambda < 130\ \mu$m) and a new developmental stage of the cold readout electronics (CRE) were carried out. Series of tests with an even more upgraded CRE version were prepared.

For the approaching routine tests of the detector lines of the FIR cameras, a suitable test cryostat was designed together with Stöhr, Augsburg, and a corresponding purchase order was placed. The IR laboratory was equipped with a conductive floor covering, which now guarantees a clean Faraday cage.

Representatives of MPIA regularly participate in training units of the team of the PACS control center (PACS ICC) and contribute to the definition of user requirements for the PACS software systems. Special working groups were established to set up important components of the PACS control center. MPIA participates in the groups responsible for calibration (as the leading institute) and commanding. In December, first drafts of the PACS calibration document and of the test procedures for the PACS chopper were completed. (Lemke, Galperine, Grözinger, Hofferbert, Klaas, Vavrek)

4.4.4 Next Generation Space Telescope (NGST)

NGST is planned to be equipped with a third focal-plane instrument that will cover the mid-infrared spectral range from 5 – 28 μm . This instrument (MIRI) consists of a high-resolution camera and a spectrometer of medium resolution. Its expected lifetime is ten years. The instrument will be built fifty percent each by American and European institutes, which will be granted guaranteed observation time in exchange for their contributions. As part of the European consortium, MPIA offers the development of all cryo-mechanics for the positioning of optical components like gratings, filter wheels and mirrors in the cryo-vacuum ($T \sim 7$ K). Due to the successful development of ISOPHOT and PACS, the Institute is well prepared for this task. In the last quarter of the year under report, a phase A study financed by ESA started under the leadership of ATC Edinburgh; to this study, MPIA will contribute the cryo-mechanics and electric design packages. (Lemke, Grözinger, Henning, Hofferbert, Rohloff)

4.5 Computing Facilities

This year too, several Sun-Sparcstation-20 computers were replaced by much more powerful new Ultra-80-workstations. Final replacement of the old SS10 and SS20 computers will occur in 2002. The data archive was moved from a CD-jukebox solution to a hard disc to allow faster and easier access from each workplace. Outdated and/or defective NCD-X terminals were replaced by thin clients, which have a significantly better price/performance relation.

For Sloan (SDSS) and CADIS each, another Nexsan-RAID system with a capacity of 1 terabyte was procured in order to store and process the ever-increasing amount of data. In addition, SDSS got a faster server computer. For the theory group, a third GRAPE-5 board was installed in the Alpha station, and the PC cluster was upgraded with 8 GB memory.

By procuring and installing a Summit-5i-gigabit switch, manufactured by Extreme Network, the foundation for a gigabit backbone was laid. The link to the Astrolabor was upgraded to 1 GB and the switch-to-switch links within the main building were led over the central Summit-5i. The electronics department was equipped with a Summit-24 to ensure fast inter-connection with the scientific network within the house and a powerful inter- connection between the computers used for developing new instruments and software.

Design software (ProE) was transferred from the previous UNIX environment to a Windows-NT environment, thus equipping almost all design workplaces with identical hard- and software. For a better and faster transfer of design data to the production process, a fast PC was set up here ensuring an inter-connection with the mechanics workshop's high-performance milling machine.

To increase the security of our computer systems against hacker attacks, safe protocols (secure pop/imap), proxy servers for ftp and http, and strict rules for internet access were implemented in the router, and all general Sun workstations were upgraded with Solaris 8. (Helfert, Hiller, Rauh, Tremmel)

4.5.1 Theory Group

In collaboration with Thorsten Naab, Andy Nelson, Michael Bertischik, Sadegh Khochfar, and Andreas Burkert, Markus Wetzstein developed a new simulation code for N-body simulations and gas dynamics. The code is characterized by very high speed. It combines various numerical strategies for rapidly calculating gravitational forces and solving hydrodynamic equations with smooth particle hydrodynamics. The special hardware GRAPE was used in particular to calculate gravitational forces. In future, this will allow simulation of objects with considerably higher resolution.

This project also resulted in a collaboration with the team of Prof. Dr. Reinhard Männer (technical computer science) at the University of Mannheim. In this project, calculation-intensive operations for gas dynamics are implemented on freely programmable chips (FPGA) using the SPH formalism (smoothed particle hydrodynamic code) to achieve higher processing speeds in gas-dynamical simulations.

5 GALACTIC ASTRONOMY: PROGRAMS AND RESULTS

5.1 Young Stars and Interstellar Matter

5.1.1 Young Binary Stars

A systematic search for young binary stars was started in the star formation region of the Ophiuchus cloud, since previous studies of this area had been of rather sporadic nature. In particular, it will be investigated whether the frequency of young binaries is determined primarily by the density of the star forming region. If so, Ophiuchus should occupy an intermediate position between the large binary frequency observed in Taurus and the small one in the Trapezium cluster. So far, analyzing of the data roughly confirms this presumption. In any case, the binary frequency in the Ophiuchus star forming region is nowhere near as high as in Taurus. (Leinert; Woitas, Tautenburg; Köhler, San Diego)

During the course of the ALFA Science Demonstration Program, spatially highly resolved spectra of the T-Tauri system were obtained using a combination of ALFA and the 3D instrument. So far, mainly the spectra of both stellar components were analyzed. From these, the extinction of the southern component was re-determined and the previous notion that it is hidden behind the accretion disk of the northern component could be refuted. In addition, AO-supported speckle observations confirmed the existence of a companion to T Tauri South at only 0.08″ distance which had already been detected before by Koresko et al. Comparison with the data of Koresko et al. allowed an initial determination of the orbit and, in combination with the spectral data, led to a new model of the T-Tau-S system. (Kasper, Feldt, Herbst, Hippler; Ott and Tacconi-Garman, MPE, Garching)

5.1.2 Temporal Evolution of the Angular Momentum of Young Stars

Within the scope of his PhD thesis, M. Lamm, together with R. Mundt and C. Bailer-Jones as well as W. Herbst (Wesleyan University), determined the rotational periods of stars in the young (2 - 4 Myr) open cluster NGC 2264 (D = 770 pc). This determination is part of an extensive program to investigate the temporal evolution of the angular momentum of young stars and to measure the angular momentum distribution of stars in clusters of various ages. As was shown by previous studies, the presence of a circumstellar disk plays a decisive role in determining the angular momentum. Stars with a circumstellar disk are rotating significantly slower than those without. A possible explanation would be a magnetic coupling of the star to the disk. This way, the disks would dissipate the angular momentum transferred from the star by magnetically driven outflows.

Large, extended stellar spots frequently form on the surfaces of young stars. The distribution of these spots is stable long enough to cause a periodic modulation of the brightness of the rotating star. Successive measurements of the brightness of a star thus enable the determination of its rotational period. NGC 2264 was observed from December 2000 to March 2001 during 44 nights using the WFI at the 2.2-m telescope of MPG/ESO. About 11000 stars with apparent *I*-magnitudes between $I = 10^{mag}$ and $I = 2l^{mag}$ were investigated this way for periodic variability, and about 600 periodic variables were discovered. Their ages have not been estimated yet. If one assumes, very pessimistically, that only 70% of these variables are young stars, this discovery means an increase of the number of young stars in NGC 2264 with known rotational period by at least a factor of 13 (from 31 to $\sim$ 400). The rotational period of the stars typically lies between 0.5 and 10 days. Stars with an *I*-magnitude of $I \leqslant 15.5^{mag}$ (that is M $\geqslant$ 0.25 M/) show a bimodal distribution of their rotational periods, with its maxima at about 1 and 4 days. Compared to the bimodal distribution of the younger Orion Nebula Cluster (ONC, age $\sim$ 1 Myr, maxima at 2 and 5 days), this means a shift towards shorter periods.

Lower-mass stars with $I \geqslant 16^{mag}$, however, show no bimodal distribution and a considerably shorter mean rotational period than the stars of the ONC. These shorter rotational periods can be explained most easily by the fact that the stars in NGC 2264, due to their older age, have smaller radii and that a significantly smaller fraction of them has circumstellar disks which can dissipate the angular momentum. Thus, for most stars the angular momentum is about constant and the shrinking of the star due to its age leads to a higher rotational velocity.

The analysis of rotational periods of young stars measured in the Orion Nebula Cluster (ONC) was continued. Basis of these measurements are the extended photometric sequences of the ONC obtained at the turn of the year 1998/1999. Rotational periods were determined for 404 stars; for 335 of them estimates of their masses made by Hillenbrand (1997, AJ 113, 1733) were available: Most of these stars have masses $< 0.3\ M_{\odot}$. Our data confirm the bimodal distribution of the rotational periods (with maxima at $\sim$2 and 8 days) for stars of masses $\geqslant 0.25\ M_{\odot}$ which already had been found for significantly fewer stars. In addition, the data show that the mean rotational period is decreasing notably towards lower masses, although the rotational period distribution for a given mass is very broad, with a variance of about a factor of 10. Our data show that the lower-mass stars rotate at about 30% of their disruption velocity while the corresponding values for solar-type stars are 5 - 10%. But this is mainly a consequence of the decrease of the disruption velocity with decreasing mass. Perhaps the most interesting result of this study is the small variation of the mean specific angular momentum J/M as a function of mass. J/M is constant at least within a factor of 2 over a mass range from 0.1 to 1 $M_{\odot}$. (Mundt, Bailer-Jones; W. Herbst, Wesleyan University, Middletown)

5.1.3 Jets from Young Stars

Analysis of HST/WFPC2 images of FS Tau and its surroundings taken in the narrowband filters Hα and [SII] as well as in the broadband filters F569W and F791W was completed. No evidence for a jet or other spatially extended flows from the young binary system FD Tau A was found. Interpretation of the data therefore concentrates on the protostellar jet of FS Tau B which was studied for the first time with a spatial resolution of 0.1″. The width of this jet is decreasing with increasing distance to its source. This unusual behavior is probably caused by re-collimation of the jet at larger distances to the source. Thanks to the high spatial resolution of the HST images, small-scale variations of the structure within the jet are visible, showing the knots of the jet as well as the maxima of the flux being correlated with minima of the jet width. The line ratio Hα/[SII], i.e. the excitation strength, is increasing with increasing distance to the jet axis. This suggests a relatively high fraction of the line emission being caused by ‘‘entrainment’’ of matter from the surroundings of the jet. (Mundt; Woitas, Eislöffel, Tautenburg; Ray, Dublin)

Analysis of the long-slit spectra of the bipolar knotty jet of RW Aur taken with HST/STIS was completed. Although the continuum of this bright classical T-Tauri star is relatively strong, it could be subtracted almost completely in the long-slit spectra. Thus it was possible for the first time to study line emission down to a distance of 0.2″ (≈ 30 AU) from the source. The STIS spectra contain the Hα line and the most important forbidden emission lines [OI], [NII], and [SII]. A total of seven spectra was taken, each with the slit placed parallel to the jet axis but with offsets of 0.07″. So, the spectra represent a three-dimensional data set (dispersion direction and two spatial directions).

From this data set it is possible to either reconstruct images of the jet in different velocity intervals or to investigate the velocity profiles of the emission lines as a function of location. The preliminary results of these studies are the following: The jet remains strongly collimated even at distances smaller than 1″ from RW Aur, and within the jet region that was investigated, the velocity profiles of the emission lines have only one maximum at v ≈ 100 km s^{-1} . Therefore, there is – as had been known already from ground-based studies – no low-velocity component of the forbidden line emission, a fact that is in strong contrast to many other jets of young stars. The velocity asymmetry between both components of the bipolar jet which was already known before (the blue-shifted component has about twice the radial velocity as the red-shifted one) already exists rather close to the source (≈ 30 AU). (Mundt; Woitas, Eislöffel, Tautenburg; Ray, Dublin; Bacciotti, Florence)

Additional analysis of the HST/STIS spectra of the jet of DG Tau showed significant differences in the radial velocities of the emission lines in the spectra of opposite sides of the jet axis. The measured differences in velocity are between 5 and 20 km s^{-1} . The measured radial velocities are corrected for wavelength shifts due to irregular illumination of the slit of the spectrograph and were measured using two different methods. If the jet is assumed to be axi-symmetric, the south-eastern part of the jet flow is moving towards the observer faster than the north-western part. If this behavior is interpreted as rotation, then the jet of DG Tau is rotating clockwise if one looks along the jet toward the source, the rotational component of the velocity being 6 - 15 km s^{-1} . These values for the rotational velocity of the jet and the values of the angular momentum flux inferred thereby are in agreement with predictions of current jet models which describe the collimation and acceleration of the jets as being caused by rotating magnetospheres. (Mundt; Baciotti, Florence; Eislöffel, Solf, Tautenburg; Ray, Dublin)

5.1.4 Extrasolar Planets, Brown Dwarfs and Low-mass Stars

C.A.L. Bailer-Jones and R. Mundt, together with D. Barrado y Navascués (Madrid), M.R. Zapatero-Osorio, R. Rebolo, V. Béjar (IAC, Tenerife), and E.L. Martin (Hawaii), continued their study of brown dwarfs found in the young (∼ 5 Myr) open stellar cluster Sigma Orionis, which partially are of very low mass. Low-resolution spectra ($R \sim 250$) of 15 brown dwarfs with planetary masses ($\lesssim 12\ M_{Jup}$) were taken using the FORS1 spectrograph at the VLT. The spectral types derived range from M9 to L5, matching well the spectral types derived from the colors. The spectra show that contamination by very late foreground or background stars is very low for brown dwarfs found previously by photometric methods and that earlier estimates of the mass function in the substellar range cannot be falsified by contamination. For 2/3 of the brown dwarfs investigated, Hα emission was detected. Presumably, this fraction would be considerably higher if spectra with higher resolution were used.

V. Béjar, M.R. Zapatero-Osorio, R. Rebolo (IAC, Tenerife), D. Barrado y Navascués (Madrid), and E.L. Martin (Hawaii), together with C.A.L. Bailer-Jones and R. Mundt, investigated the substellar mass function of the young star cluster σ Orionis. I. Baraffe, C. Chabrier, and F. Allard (Lyon) also participated in this project. This study of the substellar mass function is based primarily on photometric data taken in the I-, z-, and J band as well as recent calculations of the evolution of substellar objects. The mass function dN/dm was determined for stars of masses $\leqslant 0.2\ M_\odot$ down to the planetary mass range ($\lesssim 12\ M_{Jup}$). It turned out to increase with decreasing object mass like $dN/dm \propto m^{-\alpha}$ where $\alpha = 0.8 \pm 0.4$. This result suggests that brown dwarfs with planetary masses are as frequent as brown dwarfs with masses between 12 to 75 M_{Jup} , and that both classes of substellar objects are about as frequent as the stars of the cluster. If star formation in our Galaxy occurs primarily in star clusters (or had occurred there), as is suspected by many astronomers, a similarly high fraction of substellar objects were to be expected in the solar neighborhood as in the σ-Orionis cluster.

The search for low-mass stars and brown dwarfs in nearby star formation regions and their study were continued. These investigations are based on data obtained with the Wide Field Imager (WFI) at the 2.2-m telescope on La Silla. Suitable methods to analyze the available WFI images in search for brown dwarfs in star formation regions were developed and applied. Reduction of the available WFI images is generally completed. Photometry of the images and analysis of the results have been started.

Seventy new candidates for brown dwarfs have been found in the Chamaeleon-I star formation region from (I,R-I)-color-magnitude diagrams. All previously known brown dwarfs were identified. The Hα-emission of the new candidates was examined in order to confirm their being low-mass members of the star formation region. A photometric method to determine the spectral type of the candidates by (M915, M855-M915)-color-magnitude diagrams was developed. This method shows that almost all candidates are of spectral type M, a large fraction having a spectral type so late that most likely they have to be brown dwarfs. However, there is a small group of very faint objects for which no spectral type could be derived yet. If their substellar nature were to be confirmed (spectral type L), our survey would contain objects down to the mass limit of deuterium burning.

Using the same method, a population of brown dwarfs and very low-mass stars was found in the Lupus dark clouds (Mundt; López Marti, Eislöffel, Tautenburg).

C. Bailer-Jones continued his work on studying the atmospheres of ultracool dwarfs with time-resolved photometry as described in last year's report. This year, he focused on studies in the near infrared. Specifically, work has included observations in the J and Ks bands of three L dwarfs (with MAGIC at the 1.23-m telescope on Calar Alto, in collaboration with M. Lamm), and time-resolved spectrophotometry between 1 and 2.5 microns (with Omega Cass at the 3.5-m telescope on Calar Alto). The goal of this work is to identify the cause of the detected variability, in particular, to distinguish between dust cloud and magnetically induced star spot scenarios. The analysis of these data is underway and should be published in 2002.

In collaboration with R. Smart (Torino) and H. Jones (Liverpool), C. Bailer-Jones has started a project to measure the parallaxes of a number of T dwarfs. These are substellar objects cooler than L and M dwarfs, and have spectra dominated by molecular absorption due to water, methane and pressure-induced molecular hydrogen. Of the 20 or so objects now known, all have methane evident in the H and K band spectra. In comparison to M and L dwarfs, the differences between T dwarf spectra appear to be relatively subtle. For example, the well known parallax T dwarf Gl570D must be about 250 K cooler than Gl229B, yet their spectra are similar and bear more resemblance to the reflectance spectra of Jupiter than to L dwarfs. To properly understand the spectral differences between T dwarfs, absolute magnitudes are the most reliable method to clearly distinguish between the T dwarfs, despite these objects probably covering an order of magnitude in temperature (from around 1400 to 150 K).

The determination of stellar parallaxes remains fundamental to most observational tests of stellar structure and evolution. This paradigm remains just as important in the T-dwarf regime where, in principle, an absolute magnitude and a reliable model combined with measured temperature and surface gravity from spectroscopy suffice to determine mass and age. In turn, this determination is vital to any attempts to determine the mass function for T dwarfs. T dwarfs are very faint in the optical, where parallax work is traditionally done, so J band imaging with Omega Cass at the 3.5-m telescope on Calar Alto was used for this purpose. This is a multiyear project for which the first few measurements were successfully obtained during 2001.

5.1.5 Contributions of the ISO-170-μm Serendipity Survey to Issues of Stellar Evolution

A search for unusual galactic and extragalactic sources in the data base of the compact serendipity sources was started by cross-correlating the 170-μm- ISO data with other large-field surveys in the near and far infrared (2MASS, MSX, IRAS). Promising candidates for star formation regions as well as for galaxies with unusually high dust masses were identified.

Follow-up observations to investigate these objects in the (sub)-millimeter range were carried out on Mauna Kea (SCUBA) and on Pico Veleta (MAMBO). The combination of far-infrared measurements at the maximum of the thermal emission with the high spatial resolution of ground-based submillimeter-continuum observations enables a more detailed localization and characterization of the existing dust components. Some of the embedded stellar sources could be measured spectroscopically on Calar Alto (CAFOS, TWIN). Strong line emission observed from a dense circumstellar (accretion) region indicates the recent onset of star formation in these objects.

The cold knots identified by the 170-μm-Serendipity Survey in the nearby molecular cloud complexes in Chamaeleon, Taurus and Ophiuchus were compared to each other. At all locations, a dust temperature of about 13 K is the limit. Higher temperatures are found in the ρ-Ophiuchi cloud; they are related to an exceptionally high star formation efficiency. It was shown that the very cold knots have to be regarded as the sites of future star formation.

Preparations of the first catalogue of the coldest compact galactic knots continued. (Stickel, Hotzel, Krause, Tóth, Klaas, Lemke; Mattila, Helsinki; Müller, ESA)

5.1.6 Massive Young Stars, Ultra-compact HII Regions

From the ALFA Science Demonstration Program of 1999 and 2000, spatially highly resolved data (all better than 0.4″) of a total of 15 ultra-compact HII regions (UCHIIs) are available. In some cases, polarization measurements and long-slit spectroscopic studies were made. NIR-broadband imaging data are available for all sources. Meanwhile, all data are analyzed completely and will soon be submitted for publishing. The publication will consist of an electronic catalogue and give a first review of the mass distribution function in moderately embedded UCHIIs. More deeply embedded sources will be observed using the NAOS-IR-wavefront sensor.

Among the objects, S106 has a special position. For this object, broad- and narrowband observations as well as polarization data were analyzed. A total of almost 200 discrete sources was identified in the core of this region. With the help of the polarization data, the presence of another bright luminous source in the region – which had been assumed from MIR- and mm-data – could be excluded. (Feldt, Costa, Hippler, Puga, Weiß)

The ISOPHOT-S spectra of ten young stellar sources deeply embedded in interstellar dust were investigated for spectral features of ammonia, methanol, and methane ices. In particular, detection of ammonia ice at 9.0 μm and methanol ice at 9.7 μm requires a reliable analyzing procedure because they appear as a superimposed absorption within the strong silicate absorption band. Since the profile of the latter is not exactly known it has to be modeled by fitting a polynomial. The order of the polynomial, the number of independent data points, the width of the fitting range and the stability of the fitting algorithm have to be coordinated. To test this procedure, higher- resolution SWS spectra were used for bright sources. A very good agreement in the ice absorption lines was found. In the source W33A, all three ices were clearly detected at 7.7, 9.0, and 9.7 μm. In the sources AFGL2136, HH 100, Cep A, and NGC 7538-IRS9, the absorption lines are weaker. Ammonia ice was detected in the sources AFGL2136, Cep A, and Barnard 5 as well as methane ice in Cep A. The fraction of ammonia ice is comparable to that of carbon dioxide; the amount of water ice existing there is ten times as high. (Klaas, Ábrahám, Lemke; Gürtler, Henning, Schreyer, Jena)

5.1.7 X-Ray Absorption in Molecular Clouds

To study the influence of X-ray absorption on the chemistry of interstellar gas clouds, abundances of molecules were calculated as a function of the X-ray ionization rate. Predictions of the model were compared to the column densities measured along the line of sight towards the star Cyg OB2 No.12. It was shown that the X-rays emitted by the stars of the OB2 association dominate the chemistry of the cloud. In particular, the very large abundance of H_3^+ could be explained. As a by-product, the observations obtained with FOCES at the 2.2-m telescope led to the detection of rubidium in the interstellar matter. (Gredel; Black, Yan, Dalgarno, CfA)

5.1.8 CO Abundances in the Bok Globule Barnard 68

The spatial distribution of the abundances of CO in gaseous and in solid form within the globule Barnard 68 (B 68) was determined using radio-spectroscopic observations of low CO rotational transitions. The freezing out of the CO gas onto dust grains is quantitatively well described by a state of equilibrium between the most important adsorption and desorption processes. Important physical parameters of the globule were determined: With a distance of 80 pc and a total mass of 0.7 $M_\odot$, B 68 is considerably nearer, smaller and lighter than assumed so far. (Hotzel; Harju, Mattila, Juvela, University of Helsinki; Haikala, ESO/SEST, Chile)

5.1.9 Theoretical Work on the Evolution of Molecular Clouds and the Formation of Stars and Planets

Within the scope of his PhD thesis, M. Geyer, together with A. Burkert, studied the formation of massive gravitationally bound star clusters. The competition between efficient star formation and feedback processes determines whether a newborn star cluster is gravitationally bound or not. Ionizing radiation or winds from massive stars are able to expel the remaining gas from the cloud and so to stop further star formation. Starting from cold turbulent molecular clouds, the formation of a star cluster was simulated with an idealized star formation mechanism using the SPH formalism (smoothed particle hydrodynamic code). Stars are inserted as collision-free particles, and feedback leads to thermal heating of the surrounding gas. In the collapsing, fragmenting molecular cloud, the efficiency of star formation and thereby the binding of the system depends very strongly on how much the onset of the feedback is delayed after star formation. Moreover, the star formation history during the collapse is affected by a global criterion that determines the density at which the gas starts to be transformed into stars.

For a better understanding of how star formation processes are influenced by turbulence in molecular clouds, F. Heitsch investigated in his PhD thesis the following three questions: (1) Can magneto-hydrodynamic supersonic turbulence impede the gravitational collapse of a molecular cloud? (2) How (reliably) can measurements of magnet field strengths be obtained in turbulent molecular clouds? (3) Are external Alfvén waves a possibility to drive supersonic turbulence?

The first part of this work establishes that turbulence can stabilize a self-gravitating region as a whole but not so on small scales so that star formation cannot be prevented by turbulence. In the second part, F. Heitsch examines the Chandrasekhar-Fermi-method to determine magnetic field strengths within turbulent molecular clouds and suggests an improvement of the method as well as an empirical prescription and a correction technique which altogether considerably improve the estimate of the field strength. Finally, the last part shows that external Alfvén waves can hardly be regarded as sole drivers of supersonic turbulence in molecular clouds.

A. Nelson, in collaboration with W. Benz, continued and completed a previous project to model the migration of young Jovian planets in accretion disks. In this work, it was found that the morphology of forming planets (of order a fraction of a Jupiter mass) could be neither of a disk/core structure nor of an envelope structure. It is suggested that an intermittent rotational instability must therefore develop in an envelope, which may significantly increase the mass accretion rate and decrease the formation timescale. The results of the simulations were compared to the predictions of analytic and semi-analytic models and it was found that the analytic predictions are larger by a factor of 3 - 6 than those from the simulations. Furthermore, the analytic calculations are exquisitely sensitive to most of the common (and uncommon) approximations used to calculate them and assumptions used to derive them. Errors of order unity are easily obtainable by neglecting terms. Disk self gravity is one such term, even though the disk will be stable to self gravitating instabilities, the shifts of the resonance positions caused by its inclusion is significant. It is speculated that the width of the resonances is not negligible and that mixing between the inner and outer Lindblad resonances and the co-rotation resonances could reduce the torques to the values determined in the simulations.

In collaboration with A. Burkert, O. Kessel-Deynet developed a procedure to simulate the effects of ionizing radiation in molecular clouds using SPH. In particular, he investigated the dynamical processes during the radiation-driven implosion of molecular clouds, which turned out to be triggered by the energetic feedback by ionizing radiation from massive stars. This procedure enabled for the first time the study of the radiation-driven implosion in three spatial dimensions, taking into account self-gravitation. Small-scale perturbations of the original density distribution turned out to be able to stabilize the compressed cloud against gravitational collapse. Further investigations demonstrated the influence of ionizing radiation on the formation and evolution of filamentary structures in star formation regions. It was shown that – in agreement with the observations – star formation within these filaments is jeopardized by ionizing radiation.

B. Lang, together with A. Burkert, developed within the scope of his PhD thesis a one-dimensional model of radiative transport for SPH. The model was tested for various initial and boundary conditions. The equations of radiative transport were transferred to the SPH formalism and tested using suitable matrix solvers. A number of various self-consistent initial conditions for the collapse of a protostellar core was investigated to set up a statistical analysis of the distribution of single, double, and multiple stellar systems.

In collaboration with P. Bodenheimer and D. Lin (Santa Cruz, CA), A. Burkert investigated the heating of planetary atmospheres of Jovian planets near the sun. Unilateral heating of the planetary surface results in strong convection flows which not only produce characteristic signatures in the spectra but can also affect significantly the cooling-timescales and the internal evolution of the planets.

A. Burkert, together with P. Bodenheimer, investigated the collapse of protostellar cores and the formation of binary systems. Calculations show that internal turbulent flows significantly affect the evolution and fragmentation of the cores, leading to binary stars with a broader distribution of periods.

A. Burkert, in collaboration with M.-M. MacLow, investigated the structure of turbulent molecular clouds. Using three-dimensional numerical simulations, the surface density distribution was compared to observations in various velocity bins and it was shown that turbulence has to be driven on large scales in order to explain the structures. The mechanism driving this turbulence, however, is still unknown.

5.2 Planets, Comets, Asteroids, and Zodiacal Light

In comets, the emission at 4050 Å is caused by the resonance fluorescence in the vibration mode v_2 of the electron system $A^1\Pi_u$- $X^1\Sigma_g^+$ of the tri-atomic C_3 radical. The C_3 vibration-rotation structure was modeled in detail and compared to observations of the emission at 4050 Å from comets Hale- Bopp and de Vico. By comparison of the observations to the theoretical spectra it was possible to define more closely various molecular parameters of C_3 that had been hardly constrained so far. Allowing for transitions in the (000-000) band, particularly the observed low rotation temperature of C_3 could be explained. (Gredel; Rousselot, Besancon; Arpigny, Manfroid, Liege; Rauer, Berlin; Cochran, Austin; Fitzsimmons, Belfast)

Analysis of the spectroscopic measurements of the zodiacal light in the range of 6 - 11 μm obtained with ISOPHOT-S was continued. The spectra can be explained by blackbody radiation. Temperatures from 255 to 290 K derived for various lines of sight can be understood as natural result of the generally assumed spatial distribution of the interplanetary dust. Emission or absorption structures are not detected, indicating an efficient mixing of the interplanetary dust. There seemed to be one exception, a weak emission structure at 9.3 μm which perhaps might be explained by very small pyroxene particles. However, the location of this structure exactly at the boundary of two detector arrays suggested a calibration discontinuity to have caused it. A new, independent determination of the point spread function in the region of the affected pixels confirmed this conjecture. Therefore the spectrum of the zodiacal light in this wavelength region appears to be completely free of any structure within an accuracy of about 10%. (Klaas, Leinert, Lemke; Ábrahám, Konkoly Observatory, Budapest)

The studies of the slews of the ISO Serendipity Survey crossing planets and asteroids were generally completed. In addition to detections during rapid crossings which are included in the Serendipity Survey data base of compact objects, all parts of the slews ending at a solar system object were also studied. So now there are flux measurements at 170 μm for Uranus, Neptune, and about a dozen of asteroids available also from the Serendipity Survey. The good agreement within the flux range which is covered by direct calibration measurements as well as by model calculations guarantees an independent control of the entire calibration of the Serendipity Survey. For some asteroids previously not observed in the far infrared, ranges of values for the diameters and albedos could be restricted for the first time. At the end of the year under report, the results gathered were compiled in a manuscript. (Stickel, Hotzel, Krause, Tóth, Klaas, Lemke; Mattila, Helsinki; Müller, ESA)

5.3 Stellar Systems

5.3.1 Globular Clusters

D. Harbeck, E.K. Grebel, and G.H. Smith (UCSC, Santa Cruz) investigated the causes for variations in the chemical composition of stellar atmospheres in globular clusters. For this purpose, the absorption band of the CN molecule is used as an indicator for various chemical compositions. These variations can be caused by stellar evolution (mixing with CNO processed material) or by external processes such as self-enrichment during star formation, accretion from stellar winds or primordial variations. Using VLT spectroscopy, variations in the strengths of the CN absorption on the main sequence of the 47 Tuc globular cluster could be detected. The presence of these variations suggests external mechanisms.

A spectroscopic study of the globular cluster NGC 7006 (D. Harbeck, E. K. Grebel; G. H. Smith, UCSC, Santa Cruz), in combination with data from the literature, indicates a correlation between the proportion of CN-strong and CN-weak stars on the red giant branch and the horizontal branch morphology. If CN variations on the giant branch are caused by rotational mixing, this result suggests rotation to be a ‘‘second parameter’’ of the horizontal branch morphology.

5.3.2 Open Clusters

The spatial structure of the galactic star cluster NGC 2439 was determined using *uvby*β photometry. The photometric data were compared to known kinematic data. It was shown that NGC 2439 and the surrounding association consist of at least three star clusters that are grouped clearly in distance, radial velocity, proper motion, and extinction. From the spatial distribution of the stars and their extinction, the three-dimensional distribution of the molecular gas within the molecular cloud was determined along the line of sight towards NGC 2439 and compared to models of the formation of interstellar CH^+ . (Gredel; Kaltcheva, Sofia; Fabricius, Copenhagen)

Using HST/NICMOS observations, W. Brandner (ESO, Garching), E.K. Grebel, R. Barbá (U Nacional de la Plata, Argentina), N. Walborn (STScI, USA), and A. Moneti (IAP, France) established the presence of pre-main-sequence stars of intermediate mass in the dust filaments around 30 Doradus. 30 Doradus is the biggest HII region in the Local Group, located in the Large Magellanic Cloud. Color excesses and luminosities indicate the newly discovered stars to be

Herbig-Ae/Be stars and T-Tauri stars which probably are part of a larger, just forming OB association.

E.K. Grebel, in collaboration with D. Harbeck, A. Stolte, M. Odenkirchen, W. Brandner (ESO, Garching), A. Moffat (U de Montréal, Canada), L. Drissen (U Laval, Canada), and Y.-H. Chu (UIUC, USA), investigated the mass function of the young star cluster NGC 3603 in the Carina spiral arm of the Galaxy. Data were obtained with the Hubble Space Telescope. The cluster is only 1 to 2 million years old and has a distinct pre-main sequence bending to the main sequence. The mass function varies as a function of the distance from the cluster center: Close to the center, it is almost flat while with increasing distance it is approximating the Salpeter slope. Simulations made by P. Kroupa (Kiel) show that primordial and evolutionary mass segregation cannot be distinguished. However, a crossing time of only 24000 years is found which, in view of the high density of the cluster, corresponds to a relaxation time of only 2 million years. The cluster will probably dissolve within a few million years by dynamical evolution. Another interesting fact is that the pre-main-sequence stars in NGC 3603 appear to have only little circumstellar matter left – it was probably destroyed rather rapidly by the intense radiation field of the massive stars at the center of the cluster.

A. Stolte, E.K. Grebel, W. Brandner (ESO, Garching), and D. Figer (STScI, Baltimore) investigated the young massive star cluster Arches at the Galactic center. The analysis was done using spatially highly resolved broadband images in the near infrared (H, K) obtained at the Gemini-North-Telescope as well as HST/NICMOS photometry made available by D. Figer. The age of the young cluster is estimated by comparison with theoretical isochrones to be about two or three million years at most. The mass function was determined using isochrones and shows, as expected from the HST analysis made by D. Figer, a significantly flatter slope than common star formation regions within the Galaxy. The mass function was shown to change notably with distance from the cluster center. While it is very flat at the center, it is already exhibiting the standard slope observed in other star formation regions beyond about one half-mass radius. This is clear evidence for mass segregation in Arches, since the massive stars are concentrated primarily in the center of the cluster while the field is dominated by low-mass stars. With the data at hand, however, it was not possible to decide definitely whether the mass segregation is primordial or a result of the dynamical evolution. With the data available, no age scatter in Arches could be established.

Moreover, the HST and Gemini data were used for a detailed technical comparison between ground-based photometry with adaptive optics and observations made beyond the Earth's atmosphere. The Strehl ratio of the adaptive optics was shown to be the limiting factor of ground-based observations. Although magnitude limit as well as spatial resolution of both data sets are comparable, faint stars in the vicinity of bright objects are not resolved. If it will not be possible to improve the Strehl ratio, it will limit observations primarily of dense star fields as e.g. in star clusters or nearby galaxies.

M. Odenkirchen, together with C. Soubiran (Bordeaux), investigated the star group NGC 6994 and completed the second run of spectroscopic measurements. No significant variations of the velocities were found. From the radial velocities and the spectroscopically determined absolute magnitudes of the stars as well as from their proper motions listed in the Tycho-2 catalogue, it follows that NGC 6994 is not a remnant of an open star cluster as has been supposed repeatedly but a random clustering of physically unrelated stars in the sky.

In collaboration with S.C. Keller (IGPP, USA), K. Yoss (UIUC, USA), and G. Miller (Southwestern College, USA), E.K. Grebel analyzed the double star cluster h and χ Persei. Both components of the cluster were shown to be actually at the same distance from us. The search for emission-line objects increased the fraction of Be stars in the double cluster by about 30%. As a guest scientist, A.C. Gupta, together with E.K. Grebel, was investigating young star clusters of ages between 10^7 and 10^8 years which had been observed within the scope of a large observing campaign in order to determine distances, ages, and mass functions. In the end, these objects will be used for target selection for an accepted key project of the Space Interferometry Mission which will be launched in 2009. Analysis of the clusters is underway.

5.3.3 Astronomical Object-Classification Techniques — Preparations for the GAIA Project

GAIA is an ESA cornerstone astrometric and photometric mission to be launched around 2011. It is similar in essence to HIPPARCOS, but extending by several orders of magnitudes the astrometric accuracy, magnitude limit and number of objects. The goal is to measure positions to 10 μarcsec at V = 15 and 160 μarcsec at V = 20. It will observe the whole sky down to $V \approx 20$ about 100 times over the course of five years, observing an estimated 10^9 stars, plus numerous galaxies, quasars and asteroids. (For comparison, HIPPARCOS measured 10^5 stars in two filters down to V = 12 with an median astrometric accuracy of 1000 μarcsec for $V < 10$.) The astrometry will provide accurate positions, distances and proper motions for many of these stars. The primary goal of GAIA is to explore the composition, formation and evolution of the Galaxy by studying the dynamics and intrinsic properties of a wide range of stellar types across the whole Galaxy. GAIA will observe all objects in 15 medium and broadband filters (FWHM between 10 and 200 nm) across the wavelength range from 250 to 950 nm at a spatial resolution of at least 0.5'', although the optimization of this system continues. High resolution (0.075 nm) spectra of the brighter objects will also be obtained (with a slitless spectrograph) in the vicinity of the CaII triplet at 850-875 nm, primarily to determine radial velocities to a few km/s accuracy, thus complementing the astrometry to give a 6D phase space map of all objects down to $V \sim 18$.

As part of the GAIA Science Team co-ordinating the development of this mission, C. Bailer-Jones is leading the effort to develop the object classification techniques necessary for the enormous, multi-dimensional data set that GAIA will provide. Work in 2001 has focused on the top-level definition of the classification system as well as the optimization of the photometric filter system for determining stellar parameters.

As GAIA is a complete survey down to V = 20 without any kind of input catalogue, the first task of the classification system is to distinguish between galaxies, quasars, asteroids, and near-earth objects. For the stellar population, it is then necessary to determine the fundamental stellar parameters T_{eff}, log g, [Fe/H], [α/H], and the interstellar extinction. While the past ten years have seen a growth in the study of automated classification work, GAIA is a survey of size and complexity not yet encountered, not even in SDSS (which is ″only″ in five photometric bands, and lacks any kinematic or absolute flux information). Stellar parameterization work so far has focused on neural network classifiers using simulated GAIA data.

6 EXTRAGALACTIC ASTRONOMY: PROGRAMS AND RESULTS

6.1 Calar Alto Deep Imaging Survey (CADIS)

Participating scientists: In the year under report, the following scientists and students at MPIA participated in CADIS: Fried, Hippelein, von Kuhlmann, Leinert, Maier, Meisenheimer (Project Leader), Phleps, Rix, Röser, C. Wolf. Also involved were: Aguirre, Alises, and Prada (Calar Alto).

6.1.1 Observations and Analysis

By the end of the year 2000, more than 90% of the filter observations and about 75% of the planned Fabry-Perot observations had been carried out so that CADIS was concluded as an observational key project on Calar Alto. Since then, remaining gaps in the data base are filled through standard applications for observing time (service observations on Calar Alto). Unfortunately, in the year under report the observing schedule did not foresee enough compensation for loss of observation time due to bad weather; therefore it was impossible to complete all observations by the end of the year as planned.

For five fields out of a total of seven, data analysis was completed to such an extent as allowed by the observations available. In this process, several incorrectly adjusted Fabry-Perot wavelengths were identified which prevent an analysis of the entire scan. These images have to be repeated as soon as possible by an emergency program during ‘‘director’s time’’.

To finish CADIS, it is currently planned to catch up on all observations still missing and to complete analysis of all seven fields by the end of 2002. (All members of the CADIS team)

6.1.2 Lyman-α Primeval Galaxies

The current analysis of the emission-line survey in search for primeval galaxies with strong Lyman-α emission includes three fields in the Fabry-Perot interval A ($\lambda \approx 700$ nm, $z_{\text{Ly-}\alpha} \approx 4.8$) and four fields in the Fabry-Perot interval B ($\lambda \approx 820$ nm, $z_{\text{Ly-}\alpha} \approx 5.7$). The lists of candidates in both fields that were thoroughly cleaned from contaminating artefacts and foreground galaxies (see Annual Report 2000) already suggest that the density of bright Ly-α galaxies at $z \geqslant 4.7$ is not exceeding that at $z \approx 3.5$ and is probably notably lower. So, at $z < 5$ one would look back definitely to the period of the universe where the formation of massive stars in galaxies was significantly increasing.

By follow-up observations with FORS2 at the VLT, for the first time one of the brightest CADIS-Lyman-α candidates (at $z = 4.805$) could be confirmed spectroscopically. Conditions during the service observations, however, were too bad (bright moon) to also detect two fainter candidates. Since it was not possible to verify one of the best candidates in interval B even under better conditions, it is currently being investigated whether the (statistical) positional accuracy of very faint emission-line objects is really good enough for follow-up observations with slit widths of only 1″ while the effective resolution of the CADIS photometry is 2.3″. (Maier, Meisenheimer, Hippelein, Röser, C. Wolf)

6.1.3 Galaxies at Medium Redshift

The analysis of the global star formation rate based on the CADIS-emission-line galaxies between $z = 0.25$ and $z = 1.2$ was completed. Values were found which are even a bit higher than the results (corrected for extinction) from the UV-luminosity function. The global star formation rate has decreased since $z = 1.2$ (i.e., over about the last 10 billion years) by more than a factor of 10. Determinations of the star formation rate from various lines (Hα, [OII], [OIII]) are very consistent in implying that on average effects of metallicity are not very important.

On the other hand, based on a selection of high [OIII]/[OII] ratios, several dwarf galaxies were found at $z \approx 0.65$ that only show $\leqslant 1/10$ solar oxygen abundance. These were derived from the R_{23} = [OII] + [OIII]/H_β ratio in VLT spectra. It remains to be seen whether an abundance distribution deviating from the local universe can also be established for a larger sample. (Hippelein, Maier, Meisenheimer)

6.1.4 Evolution of the Large-scale Structure of the Universe

The analysis of the sample of 4500 galaxies with roughly known redshifts from the multi-color survey ($\sigma_z \leqslant 0.02$) was continued and extended. The result in four redshift intervals $z \approx 0$ (from the Las Campanas Redshift Survey), $0.2 < z \leqslant 0.5$, $0.5 < z \leqslant 0.75$, and $0.75 < z \leqslant 1.07$ shows for galaxies as a whole a decrease of the correlation amplitude $\propto (1 + z)^{-1.9}$. It was shown for the first time that the correlation amplitude of early-type galaxies (E to Sa) is notably above that of all galaxies even at $z \approx 1$ and therefore has to increase only by a small amount to reach the value presently observed. (Phleps, Meisenheimer)

6.2 Extragalactic Astronomy with ISO

6.2.1 Galaxies

It was investigated whether the PAH emission in galaxies is based primarily on starburst activity or is rather caused by ubiquitous PAH rings in the galactic dust excited by the interstellar radiation field.

Comparisons of the PAH emission bands at 7.7 μm with the submillimeter continuum at 850 μm were continued, the idea being that the submillimeter continuum indicates the real distribution of interstellar dust not falsified by extinction and that the strength of the PAH emission can be quantified by that measure. The PAH/submillimeter flux ratio of five spatially resolved galaxies was investigated, the galaxies covering a range from low star formation activity up to violent starbursts. The data archives of ISO and JCMT provided the mid-infrared spectra and broadband maps obtained with ISOPHOT-S and ISOCAM as well as submillimeter maps at 850 μm obtained with SCUBA.

Analysis of the spectra and maps revealed the following: In each of the five galaxies the morphology follows the PAH emission at 7.7 μm and that of the cold dust at 850 μm. The flux ratio of the PAH emission at 7.7 μm to the continuum at 850 μm is for all spatially resolved regions within the five galaxies around 2 $\pm$ 0.5. Remarkably, this ratio does not increase in regions of violent starbursts. This shows that starbursts apparently are playing a minor role in the origin of PAH emission in galaxies; the main contribution to the PAH emission of a galaxy comes from PAH particles ubiquitously mixed with the cool galactic dust and excited by the interstellar radiation field. In this picture, the amount of dust correlates with the strengths of the PAH emission, and at the same time the presence of more interstellar matter is also responsible for an increased probability of star formation. In addition, the spatially resolved studies of the five galaxies show the following: In most of the regions, the PAH emission as well as the submillimeter emission of the cold dust correlates with the intensity of the mid- infrared emission of the warm, small dust grains at 14.3 μm. Only starburst regions clearly show an excess of mid-infrared radiation by factors of 2 to 7.

These findings possibly have consequences for the cosmological interpretation of galaxy counts in the mid infrared at 15 μm. PAH emission bands at redshifts between $z = 0.5$ and $z = 1$ fall into this observation window. Assuming implicitly that PAHs are illuminated considerably only by starbursts, the observed excess of sources fainter than 0.3 mJy was attributed so far to starburst galaxies. From this, an epoch with a significantly higher frequency of luminous interacting systems than today was concluded. But if the PAH emission is not caused primarily by starbursts, less exotic large spiral galaxies rich in dust and PAHs also could explain the galaxy counts in the mid infrared. (Haas, Klaas; Bianchi, ESO)

6.2.2 ISOPHOT Serendipity Survey

A first complete reduction of all raster maps at 170 μm of the ISO Archive in VILSPA that contain compact sources of the Serendipity Survey database was finished. Work on the next catalogue of compact Serendipity sources associated with galaxies continued. For this purpose, all suitable Serendipity crossings were examined individually to generally reject unreal associations caused by remaining detector effects, impacts of cosmic particles, and, particularly, cirrus structures. For a significant fraction of the compact sources, it was impossible to eliminate all perturbing cosmic particle signals automatically. The accuracy of the source fluxes obtained could be improved considerably by interactive reprocessing, thereby improving the quality of the derived properties of the entire catalogue containing about 1000 objects.

6.2.3 Dust in Galaxy Clusters

The analysis of ISOPHOT data in order to search for dust within the hot gas of six Abell galaxy clusters was generally completed. The raw data had shown systematic variations of the 120 μm/180 μm color temperature in three of the six clusters. At the same time, however, simple one-dimensional models showed the faint zodiacal light to affect the color profiles. While subtraction of the zodiacal light does hardly change the observed brightness, the systematic variations of the color profiles disappear in two of the three galaxy clusters. Only for the Coma cluster no significant change occurred. The different profiles in two clusters before and after subtraction of the zodiacal light are most easily explained by cirrus structures within the Milky Way Galaxy. Remarkably, these two clusters are those candidates for which evidence of intracluster dust had been found by two-dimensional analysis of IRAS data. According to our study, Coma remains the only cluster for which a small fraction of intergalactic dust (gas/dust $\sim$ 10000/1) is detected. The report of the results was accepted for publication by A&A in the year under report. (Stickel, Klaas, Lemke; Mattila, Helsinki)

6.2.4 Infrared Background Radiation

All mappings of fields that do not contain bright individual sources were extracted from the extended ISOPHOT data base. They were used to determine the values of the confusion noise as a function of wavelength and integral surface brightness for the wavelength range of 90 to 200 μm. Using these diagrams and taking into account the telescope aperture, the limit of the confusion noise of future infrared space telescopes can be predicted with high certainty. For the darkest fields, the fraction of cirrus noise could be distinguished from the fluctuations of the extragalactic background. So it was possible to determine the upper limits of the cosmic background radiation (CFIRB) at 170 μm (νI_ν = 14 $\pm$ 3 nW m^{-2} sr^{-1}) and 90 μm (37 nW m^{-2} sr^{-1}). This determination was the second independent contribution to the determination of the CFIB from ISOPHOT data, after galaxy counts in long-exposure fields already had provided lower limits. Work on the direct determination of the CFIRB was continued by carefully discriminating all foreground components and instrumental effects. In particular, important improvements of the calibrations were achieved with respect to the cirrus and zodiacal light as well as for scattered light and of the detectors. (Lemke, Ąbrahám, del Burgo, Héraudeau, Kiss, Klaas; Mattila, Juvela, Helsinki)

6.2.5 Dust Properties of the Small Magellanic Cloud (SMC)

In the course of the ISO mission, extended mappings of the SMC had been carried out at 170 μm using ISOPHOT. The resulting individual fields were combined to construct a total map, achieving an excellent spatial resolution with a pixel size of only 15″ after an elaborated restoration procedure. A fully automated iterative procedure was used to detect extended and point-like sources. In order to study comparable data from adjacent wavelength regions with the same method, SMC maps at wavelengths of 12 μm, 25 μm, 60 μm, and 100 μm made available by IPAC in the high-resolution mode were used. The fully automated method was able to determine reliably the spatial distribution and brightness of the sources, even in regions rich of sources and in the two mid-infrared bands of IRAS. (Wilke, Stickel, Haas, Klaas, Lemke)

6.3 Galaxies

6.3.1 Evolution of Galaxies

G. Rudnick and H.-W. Rix, together with colleagues from Leiden (M. Franx, I. Labbe) and Garching (A. Moorwood), investigated the evolution of galaxies since $z \sim 3$ using deep near-infrared images. Within the scope of the FIRES project (Faint Infrared Extragalactic Survey), the deepest K-band image of the Hubble Deep Field South was obtained with the VLT. Within the scope of his PhD thesis, G. Rudnick developed improved methods to estimate photometric redshifts from data in U, V, R, I, J, H, and K bands. With this work, it was possible for the first time to investigate large samples of high-redshift galaxies systematically for their (rest frame) optical properties. It was shown that at $z \sim 2$ at least as much stellar mass is contained in galaxies which were not found as Ly-break objects as in the Ly-break objects themselves. Furthermore, it was shown that at least some large disk galaxies are existing at $z \sim 3$.

Within the scope of his PhD thesis, T. Kranz, together with A. Slyz and H.-W. Rix, investigated the question how much dark matter exists within the inner parts of spiral galaxies. The basic idea is that star disks have (non-axialsymmetric) spiral arms while the kinematically hot halos of dark matter do not. The mass contained within the spiral arms therefore will cause corresponding perturbations in the gas velocity field which can be measured, e.g., through the Hα-line. For this purpose, K-band images of spirals were obtained from which maps of the star mass are derived, except for the scaling factor M/L. A newly developed color correction was used for this. Hydrodynamic simulations for various ratios of (axisymmetric) dark halos and star mass (with spiral arms) were carried out using a code developed by A. Slyz to predict the morphology of the gas shock and the gas velocities. It was shown that the pattern speed of the spirals can be determined fairly accurately by comparing the simulated spiral morphology with the observed one; the co-rotation radius of all five spirals studied lies at 3 scale lengths and always just outside the continuous spiral arms. Moreover, the studies showed a stellar mass fraction of about 70% of the maximum value for spirals of high surface brightness to be typical.

6.3.2 Search for Galaxy Clusters

The follow-up observations of the southern survey field 287 in the I-band with the WFI on La Silla in search for distant galaxy clusters were completed in May. Within the scope of a diploma thesis, reduction and analysis was started. The quality of data turned out to be affected strongly by extremely prominent interference patterns in the detector (fringes). Only after numerous attempts could a procedure be established that reduces the remnant fringe amplitude in the sky background significantly to below one percent. The core of the procedure is a chip-by-chip flat field correction after an exact background modeling as well as an exact determination of the background light that does not contribute to the fringes. After the analysis of the currently achieved magnitude limits, the cluster candidates identified by O. Baumann are planned to be verified in the WFI data. (Tschamber, Röser; Hawkins, MacGillivray, Edinburgh)

Photometric redshifts derived from multi-color data sets, which are provided, e.g., by CADIS or COMBO 17, offer optimal possibilities to find distant galaxy clusters. In preparation for a planned extensive search for such clusters with LAICA and OMEGA2000, the development of an adapted procedure for the search for galaxy clusters was started to be developed using object lists from CADIS and COMBO 17. In a first step, the number density of objects within concentric rings around each object is determined and compared to a random distribution. Objects with over-densities in their immediate surroundings are candidates for galaxy clusters. This analysis is done in a tabular calculation. The objects that are to be included in the analysis can be selected by filtering for detailed characteristics of each object contained in the table. This way, it is possible to investigate, e.g., the accumulation of objects of a certain color, thereby optimizing the search.

In a second step, the photometric redshifts are included in the analysis. For each galaxy, the number of neighboring galaxies – on the celestial sphere as well as in radial direction – is determined: Based on the photometric redshift of the galaxy inspected, the angular range is calculated that corresponds to a given fraction of the projected Abell radius at this redshift. In addition, those galaxies are searched for that are located, according to their photometric redshift, within a given redshift interval around the redshift of the galaxy inspected. For each galaxy, the objects meeting both requirements are counted. Candidates for galaxy clusters stand out as objects with particularly numerous neighboring objects. This way, the search is carried out in three dimensions; contamination by field galaxies is minimal. Using this method, a galaxy cluster candidate at $z \approx 0.6$ has already been found in the CADIS-1h-field – in spite of the relatively small area of the CADIS fields. (Röser; Wolf, Oxford)

6.3.3 Galaxy Clusters around the Most Distant Radio Galaxies

In collaboration with B. Venemans, G. Miley, H. Rottgering, and J. Kurk of the Observatory Leiden, L. Pentericci continued the search for newly forming high-redshift galaxy clusters in the fields of selected distant radio galaxies. The observations are part of a VLT large program that has been allocated 18 nights at the VLT. In 2001, deep narrowband images of several fields were obtained to select candidates for Lyα emitters which are located at the same redshift as the central radio source. Spectroscopic follow-up observations were made in two of the fields. In particular the field of the radio source 1338 -1942 proved to contain perhaps the most distant structure known, a proto-cluster at $z = 4.11$.

Pentericci confirmed the membership for at least 21 galaxies, which have velocity-offsets of order a few 100 km/s and are located at a distance of less than 2 Mpc from the central radio source. Their spatial distribution is not homogeneous and is elongated along the same direction as the radio source. The velocity distribution is nearly Gaussian and indicates a mass of $1 \times 10^{14}\ M_{\odot}$ (if virialized).

Also in collaboration with J. Kurk, G. Miley, and H. Rottgering, L. Pentericci completed the investigation of the structure around 1138 -262 (at $z = 2.2$) discovered previously. With VLT multi-wavelength narrow- and broadband imaging she was able to reveal the presence of Hα-emission galaxies at the same redshift, as well as several Extremely Red Objects (EROs), which could be the evolved galaxy population of the proto-cluster. Among other things, the morphologies, star formation rates, and other properties of the cluster-galaxies were investigated.

Together with C. Carilli and D. Harris, L. Pentericci obtained X-ray observations of the same radio galaxy 1138 -262 with the Chandra Telescope. These observations show that the X-ray flux from 1138–262 is dominated by emission from the active galactic nucleus (AGN) with a 2 to 10 keV luminosity of 4×10^{45} erg s^{-1} . The X-ray and radio properties of the AGN in 1138 -262 are similar to those of the AGN in the archetype powerful radio galaxy Cygnus A. The extended X-ray-emission region is elongated with a major axis aligned with that of the radio source. Its most likely origin is thermal emission from shocked gas, although a contribution from inverse Compton emission cannot be ruled out.

6.3.4 The L_x -σ-Relationship for Poor Groups of Galaxies and Optical Properties of Poor Groups of Galaxies

In collaboration with A. I. Zabludoff (University of Arozona) and J. S. Mulchaey (Carnegie Observatories), M. E. Zimer is working on the L_x - σ-relationship for poor groups of galaxies and on the optical properties of such groups.

The results on both topics clearly show the importance of taking a closer look at the poor groups to get robust velocity dispersions (σ), good dynamical properties and deep velocity distributions. A sample of 20 poor groups of galaxies was used to study the L_x -σ-relationship at low X-ray luminosities (L_x). Redshifts for fainter members and deep X-ray imaging of these groups were obtained. It was found that the L_x-σ-relationship derived for the rich clusters is consistent with the data for the selected 20 poor groups. This result is reinforced by numerical simulations which indicate that in the absence of non-gravitational heating the density profiles of groups and clusters should be nearly identical. However, the nature of the scaling relationships for groups and clusters has proved to be very controversial as various authors claim a steeper relationship for groups than for rich clusters. This may be explained if preheating by an early generation of stars increases the entropy of the system, which in turn prevents gas from falling into the potential well. This effect is stronger for lower mass systems, so the X-ray luminosities of groups would be reduced more strongly than the luminosities of rich clusters. In these previous surveys, the velocity dispersions were determined from only three or four of the brightest group members, while Zimer found typically 15 - 30 group members so that the calculated velocity dispersions are more robust.

6.3.5 Nearby Dwarf Galaxies

Spheroidal dwarf galaxies exhibit the lowest mass and, at the same time, lowest luminosity of all dwarf galaxies known. D. Harbeck and E.K. Grebel carried out a systematic study of these galaxies to search for spatial variations in the star formation history. In many cases, radial gradients are found indicating that star formation is concentrated within the central regions and has continued there for a longer period of time than in the outer parts. These gradients even occur in a number of dwarf galaxies that are dominated by old populations, manifesting themselves as variations of the morphology of the horizontal branch. Red, massive horizontal branch stars are concentrated more strongly to the center than the lower mass blue ones. The opposite trend was found in none of the nine galaxies observed in this study. If such a gradient occurs among the horizontal branch stars, then it is accompanied by a stronger concentration of the stars of the red part of the red giant branch. This fact might imply a metallicity effect. Follow-up spectroscopy is planned for the next year.

Within the scope of his diploma thesis, M. Zimer, together with D. Harbeck and E.K. Grebel, is conducting an analysis of the variable stars in Fornax, a nearby spheroidal dwarf galaxy. After determining light curves and periods, these data will be used for an investigation of the depth structure of the dwarf galaxy.

The morphology of the spheroidal dwarf galaxy Carina was investigated by star counts in a four square degree field around the galaxy down to the 23.3^{mag} limit. The position of the objects was determined astrometrically with 0.3″ accuracy while photometry was done with 0.2^{mag} accuracy. A density profile was determined on concentric ellipses around the center of the galaxy.

The radial density profile is approximated well by a theoretical King profile with a core radius of $r_c = 18'$ and a tidal radius of $r_t = 50'$. In contrast to previous observations, no evidence for a tidal tail is found. From this, it is concluded that there is no evidence for interaction with the Milky Way Galaxy. Therefore, this galaxy could be dominated by a halo of dark matter which prevents the formation of tidal tails. (Fried, Walcher)

6.3.6 Dwarf Galaxies in the Local Volume

In collaboration with a US-American-Chilean-Russian team, E.K. Grebel is carrying out a systematic study of dwarf galaxies and low-surface-brightness galaxies (LSB) within a volume of about 5 Mpc (“Local Volume”). After identification on photographic plates and verification by ground-based CCD images, 150 candidates for dwarf galaxies have been observed so far within the scope of two HST- Snapshot Surveys and, in many cases, have been resolved into individual stars. These data enable the determination of distances based on the tip of the red giant branch as well as a derivation of the recent star formation history. With these data, the three-dimensional structure of two nearby galaxy groups could be determined for the first time (M81 group, CenA group; PI: I. Karachentsev, SAO, Russia). The distance estimates were complemented by the determination of radial velocities, thereby allowing an estimate of the masses of the central galaxies as well as the entire groups. Work on other nearby groups as well as on the investigation of the velocity field within the Local Volume is in preparation.

As NSF-Fellow at MPIA and in collaboration with E.K. Grebel and P. Hodge (U. Washington), D. Zucker carried out ground-based observations of dwarf galaxies within the Local Volume which are used for the determination of structure parameters and for target selection for emission-line spectroscopy. As INTAS-Fellow and in collaboration with E.K. Grebel and J. Karachentsev (SAO, Russia), L. Makarova (SAO, Russia) determined structure parameters and integrated values of the dwarf galaxies; she is continuing this work in Russia. H. Lee (U. Toronto, Canada; presently at MPIA), together with E.K. Grebel and P. Hodge (U. Washington), conducted spectroscopy of gas-rich dwarf galaxies in nearby groups in order to determine their oxygen abundances by means of the emission lines. This work, too, is continued. The ultimate goal of these studies is to derive a global picture of the properties of galaxies in groups, of the evolution of these galaxies and the effects of their surroundings.

6.4 Active Galaxies and Quasars

6.4.1 Galactic Nuclei

Within the scope of his PhD thesis, M. Sarzi, together with H.-W. Rix, G. Rudnick and colleagues in the USA (J. Shields, Ohio; L. Ho, Carnegie; A. Barth, Harvard), has completed the investigation of galactic nuclei and, particularly, their black holes based on HST spectroscopy data. Within the scope of the SUNNS project (Survey of Nearby Nuclei with STIS), M. Sarzi and A. Barth have developed methods to estimate as precisely as possible the masses of black holes. With these methods, the point is to find out in which cases the gas kinematics actually reflects orbital motion and how to model the often large velocity dispersion of the gas. Using these methods, it was possible to partly estimate very precisely (with 20% accuracy) the masses of the central black holes for five new objects; the scatter in the so-called M-σ-relationship, it turned out, is decreasing still further with increasing precision of the mass estimate. Moreover, it was shown by means of the mass estimates of black holes for a complete galaxy sample that there can be only very few exceptions from this M-σ-relationship. Through an analysis of the stellar populations within $R = 0.2''$, M. Sarzi was able to show that also in so-called HII cores, i.e. in galaxies with young stars allegedly lying in the center, these young stars actually are lying in almost all cases on a circum-nuclear ring and not, as in our Milky Way System, exactly in the center.

H.-W. Rix and M. Sarzi, together with T. Böker (STScI), continued their study of the centers of late-type galaxies, i.e. galaxies with no bulge. The basic question here is, whether in these galaxies, too, the (geometric) center has unusual properties. A first result, based on a HST Snapshot Survey, showed, that about three quarters of all bulge-free galaxies have a central star cluster as a core. These clusters typically have luminosities similar to those of globular clusters. It was shown that these cluster are lying at the true center of the galaxy.

6.4.2 Gravitational Lenses

In collaboration with colleagues at CfA (particularly J. Winn and C. Kochanek), H.- W. Rix continued his study of gravitational lenses within the scope of the CASTLES project. With PKS 1830 -211, it was shown for the first time that face- on spirals, too, can act as gravitational lenses.

As visiting scientist at MPIA, E. Ofek (Tel Aviv), together with H.-W. Rix and F. Prada (CAHA), carried out a search for gravitational lenses with wide image separation ($> 10''$). As potential image pairs, firstly radio-loud quasars were extracted from the FIRST Survey and then follow-up studies of theses candidates were carried out on Calar Alto. Of about 10000 quasars, not a single one is lensed with an image separation $> 10°$. This result already restricts some models of mass profiles of galaxy clusters (the potential lenses). The search is continued currently on the basis of SDSS quasars.

6.4.3 The Jet of 3C273

High-resolution studies: Data obtained with the radio telescopes of the Very Large Array as well as infrared, optical and UV data obtained with HST were combined with unprecedented $0.3''$ resolution. These observations show that the spectrum of the jet decreases more slowly in the UV than expected according to simple synchrotron theory, which is a rather surprising result. Therefore the emission of the jet can no longer be interpreted as synchrotron emission of a single electron distribution. The flat run of the high- frequency spectrum as well as the X-ray emission of the jet can be explained by a model which suggests two different electron distributions emitting synchrotron radiation, the X-ray emission and part of the UV emission of the jet being of common origin.

The new observations were combined yielding synchrotron spectra which allow the determination of the maximum energy of the emitting particles. The decrease of the maximum energy along the jet is much slower than estimated directly from the observed synchrotron losses (decrease of the maximum Lorentz factor from $> 10^6$ to 3×10^5 over 60 kpc). Nevertheless, no evidence is found for spatially limited regions in which particles are re-accelerated. These results confirm the conclusion that particles are re-accelerated over the whole length of the jet of 3C 273. (Jester)

Inner region of the jet: Observations of the jet in B, R, and I obtained with the FORS instrument at the VLT detected for the first time high-frequency emission from the inner half of the jet beyond any doubt. It comes from a radio knot of the jet at about 7° (20 kpc) distance from the core of the quasar. The analog infrared observations with ISAAC had not been carried out in the service mode but were re-applied for and got scheduled with higher priority. (Jester, Röser, Meisenheimer, B. Miller (summer student, MIT); R. Perley, NRAO)

6.5 Sloan Digital Sky Survey (SDSS)

The Sloan Digital Sky Survey (SDSS) images a quarter of the entire sky in five optical broadband filters down to a magnitude limit of $R \sim 23^{\mathrm{mag}}$. Subsequently, all galaxies with $R < 18^{\mathrm{mag}}$ and all quasars brighter than $\sim 19^{\mathrm{mag}}$ are studied spectroscopically (about 3 Å resolution over a wavelength region of 3900 Å to 9100 Å). In April 2000, the SDSS started its regular observations with a 2.5-m telescope built for this purpose at Apache Point Observatory, USA. SDSS data are reduced by an automated software and made available to the participating institutes. MPIA participates since 1999 in the international SDSS collaboration. At MPIA, presently W. Dehnen (data archive), E.K. Grebel (PI), D. Harbeck, A. Kniazev, M. Odenkirchen, L. Pentericci, P. Prada, and H.-W. Rix have access to non-public SDSS data. The main projects conducted at MPIA are described below.

6.5.1 Public Data Archive

After a period of 1.5 years, SDSS data have been made accessible to the public. To complement the data centers in the USA and Japan, MPIA, together with the MPI für Astrophysik and the MPI für extraterrestrische Physik, have established a mirror site that is located in Garching and will provide rapid access to the public SDSS data to the German and European astronomer’s community. Hardware for the mirror has already been purchased.

6.5.2 The Calar Alto Key Project

In order to ensure optimal exploitation of the SDSS data, a new key project was started as a successor project to the CADIS Survey: The ‘‘Calar Alto Key Project for SDSS follow-up Observations ‘‘ (PI: Grebel). As for the SDSS, the duration of this project is five years. Per semester, 40 $\pm$ 5 observing nights are available at the 3.5-m and 2.2-m telescopes on Calar Alto. Observations are carried out by P. Prada and colleagues in service mode. Part of the time is reserved for long-term projects at MPIA and other participating institutes, while the rest is used for ‘‘target of opportunity’’ observations. Observing time is allocated on a monthly basis to ensure as high a flexibility as possible. Current long-term projects include the determination of JHK colors of SDSS quasar candidates, of rotation curves of spiral galaxies, follow-up observations of dwarf galaxies identified in the SDSS, the kinematics of stars in tidal tails of globular clusters identified through SDSS data as well as the compilation of a library of spectra with SDSS resolution for population synthesis.

6.5.3 High-redshift Quasars in the SDSS

All work on this project was carried out by L. Pentericci in collaboration with H.-W. Rix as well as X. Fan, M. Strauss, and V. Narayanan (Princeton).

The quasars with the highest redshifts. Following the discovery of the most distant quasar known to date, SDSS J1030+0524 at redshift $z = 6.28$, VLT observations were obtained with Director’s Discretionary Time (Pentericci, Rix). From FORS2 high resolution optical spectroscopy, we confirmed the presence of a complete Gunn-Peterson trough caused by neutral hydrogen in the intergalactic medium. There is no detectable flux over the wavelength range from 8450 to 8710 Å. With these observations we could set a strong limit on the drop of the flux level blueward of the Lyα line: a factor of > 200.

We also analyzed the spectrum below 8450 Å where we observed a rise in flux, with a large fraction ($>$ 60 %) of the total emission produced by few narrow features of transmitted flux. Another interesting feature analyzed was the proximity effect around this quasar. In a region of about 23 h^{-1} Mpc (comoving) flux is transmitted with many absorption features present. From the size of this region we derived a lifetime for the quasar of $\sim 1.5 \times 10^7$ years.

We also obtained near-IR spectroscopy of both SDSS J1030+0524 and of SDSS J1306+05, the second most distant quasar known at redshift 6.0. Combining measurements of the CIV line and limits on the HeII emission from the near-IR spectra with the NV line measurements from the optical spectra, we could derive line ratios, and by implication the metal abundances of these early quasar environments. The results were indistinguishable from those of lower redshift quasars and indicate little or no evolution in the metal abundances from $z \sim 6$ to $z \sim 2$. The line ratios suggest supersolar metallicities, implying that the first stars around the quasars must have formed at least a few hundreds of Myr prior to the observation, i.e., at redshift $z > 8$. A refereed paper on these results is in press.

Calar Alto observations of high redshift quasars and candidate quasars. We continued our Calar Alto campaign (started in 2000) to obtain near-IR (J,H,K) complete photometry of a color selected sample of high redshift quasars from SDSS. The observations were performed with the MAGIC camera on the 2.2-m telescope. During several photometric nights, data were obtained for a large set of objects ($\sim$ 30 quasars with redshifts between 4 and 5). The data are being analyzed at the moment in order to determine the near-IR properties and compare them to the low redshift ones. During the non-photometric nights, the MAGIC camera was used to obtain J-band snapshots of i-band drop-outs in order to find high redshift quasars. The list of targets was produced by X. Fan from SDSS photometry, by selecting those objects with very red (i - z) colors (and in some cases objects that have a solid detection only in the z band). These objects are either extremely high redshift quasars or L- or M-dwarf stars. By obtaining J- band photometry, we can first of all confirm the reality of the detections, and secondly determine the (z - J) color that can discriminate between the above classes of objects. Data were obtained for approximately 40 objects: all those showing relatively blue (z - J) color (in general (z - J) < 2) were then observed spectroscopically elsewhere to determine the redshift. Among the targets that were observed there is also SDSS J1306+05, the second most distant quasar known at redshift 6.0.

6.5.4 Rotation Curves and the Tully-Fisher Relationship

H.-W. Rix, in collaboration with D. Weinberg, J. Pizagno (Ohio State University, USA), and P. Prada (Calar Alto), is investigating the rotation curves of 200 spiral galaxies identified in the SDSS in the velocity range of 5000 to 8000 km

s^{-1} . Long-slit spectra required for this study are obtained with the TWIN spectrograph on Calar Alto. The goal of the study is to measure the potential barriers of the galaxies in a mass range from 0.1 to 3 L^* as well as the investigation of the scatter in the Tully-Fisher relationship as a function of luminosity and wavelength.

6.5.5 Dwarf Galaxies in the SDSS

Search for Low-Surface-Brightness Galaxies in SDSS images. We are carrying out a search for low-surface-brightness (LSB) galaxies using SDSS imaging data (A. Kniazev, E.K. Grebel). As a first step we used a test sample of 92 well-known LSB galaxies situated in 93 SDSS fields of the Early Data Release (EDR). Our analysis shows that the EDR photometry yields a very large fraction of false candidates (even when applying the most stringent selection criteria) and misses about 1/3 of the known LSB galaxies. To overcome these problems, new photometry software to deal with SDSS data was created (Kniazev). It was tested on both SDSS stellar objects and on photometry for test-LSB galaxies and other bright galaxies and gave well consistent results. Using this new software, 87 of 92 known LSB galaxies were recovered (94.5% detection rate), and about 20 new galaxies with similar parameters were found on the same frames. In addition, we determined the main photometric parameters of all the identified LBS galaxies.

SDSS as a tool to study galaxy metallicity distribution and to search for the most metal-deficient gas-rich dwarf galaxies. A. Kniazev uses SDSS spectra of emission-line galaxies to measure their oxygen abundances. Another important goal of this study is to optimize the search for the most probable candidates for very metal-poor star-bursting galaxies. We developed software to measure emission lines in SDSS spectra and we established selection criteria for galaxies from the SDSS database in order to extract the candidates with measurable O/H. The selection criteria are based on the comparison of results for the same galaxies obtained from the SDSS spectra and from earlier high quality data. For galaxies with a redshift lower than 0.024, the [OII]-line λ 3727 Å is either outside the SDSS spectral range, or is very close to the edge, and its intensity is determined with large uncertainties. Therefore a different method was employed to determine the abundance of O^+ by using the [OII] doublet at λ 7319,7330 Å. We did not find real low-metallicity galaxies from EDR-data but created a list of candidates of interest for follow-up spectroscopy. During our search of proprietary SDSS spectral data three new low-metallicity galaxies were found.

6.5.6 Studying the Galactic Structure with the Help of SDSS

Tidal tails of globular clusters. M. Odenkirchen, in collaboration with E.K. Grebel, W. Dehnen, H.-W. Rix, and F. Prada (Calar Alto), continued their investigation of the spatial structure of globular clusters and spheroidal dwarf galaxies around the Milky Way System. Particular attention was paid to the faint globular cluster Palomar 5 which is characterized by heavy mass loss. With the progress of SDSS an equatorial zone of 7 degrees total width of photometric data became available in the region of Palomar 5. Thus it was possible to examine the wider surroundings of the cluster. It was found that the tidal arms of Palomar 5, which had been discovered in the previous year, are extending to considerably larger distances from the cluster's core. The stars stripped from the cluster by tidal interactions with the Milky Way Galaxy are distributed along a slightly bent arc about 30 arcminutes wide. It spans 10 degrees on the sky in total, corresponding to more than 4 kpc in space. From the number of former cluster members detected in a magnitude range between 19.5^{mag} and 22.0^{mag} (in the *i*-filter) it is concluded that the tidal tails contain about 1.2 times as much mass as remains in the cluster itself. At least the southern tail is assumed to stretch beyond the region examined so far.

To determine the internal kinematics of Palomar 5, which has not yet been investigated, spectra were taken of a number of stars with magnitudes 15^{mag} to 17^{mag} lying within the cluster's radius using the UVES spectrograph on the VLT. From these, radial velocities were obtained with high accuracy, yielding a very small velocity dispersion for the cluster stars of 0.9 km s^{-1} at most. This is an absolute minimum compared to values measured for other globular clusters up to now. The velocity dispersion measured suggests significant contributions from binary stars. Therefore, Monte-Carlo simulations with binaries were carried out. Comparing the results of the simulations with the observations indicates a probable fraction of binaries of 40% to 60%. The dynamical fraction of the velocity dispersion is estimated to be only 0.25 km s^{-1} .

The change in the mean radial velocity along the galactic orbit, i.e. the tidal tails, which has been measured for the first time through Palomar 5, is an important quantity in order to determine the potential within the Galactic halo. The velocities of bright stars in the tidal arms were measured using the TWIN spectrograph at the 3.5-m telescope on Calar Alto in order to kinematically identify former members of the cluster. It turned out that three out of seven candidates examined in the region of the tidal tails of Palomar 5 are kinematically belonging to the cluster. Therefore the measurements are planned to be continued at larger angular distances from the cluster.

In order to study the luminosity function in the tidal arms of Palomar 5, deep images of two fields in the knots of the tidal arms and of a comparison field were taken with FORS at the VLT. Analysis of these observations is in progress as part of the diploma thesis of A. Koch. Results will be compared to the luminosity function of the inner part of the cluster recently derived from HST observations (Grillmaier & Smith 2001) to show possible differences due to mass segregation.

Simulations of the formation and evolution of the tidal arms around the halo globular cluster Pal 5, described already in the Annual Report 2000, were refined (Dehnen). In particular, the large parameter space was illuminated in more detail, confirming the essential facts described last year. But now, a detailed comparison with the observations, particularly the small velocity dispersion and the internal structure of the tidal arms, also reveals some problems. More simulations are needed to clarify whether and how these data are to be understood.

Search for structure in the galactic halo. H. Newberg (RPI, USA) and B. Yanny (Fermilab, USA), together with Dehnen, Grebel, Odenkirchen, Rix, and other members of the SDSS collaboration, found evidence for new substructures within the galactic halo. In contrast to the overdensities detected last year, these newly found structures cannot be attributed to the Sagittarius dwarf galaxy which is currently accreted by the Milky Way Galaxy. Instead, they could be either components of a – in this case – much more extended, thick galactic disk or another dwarf galaxy presently being disrupted. Together with R. Ibata (Observatoire de Strasbourg, France) and G. Lewis (AAT, Australia), we have been allocated observing time at the AAT for more detailed follow-up studies in order to determine the kinematics of the candidate member stars.

Determining the structure of nearby dwarf galaxies by means of individual stars. Following a previous study of the Draco dwarf galaxy with SDSS data, candidate members along both main axes of Draco were spectroscopically analyzed using the MOSCA spectrograph at the 3.5-m telescope on Calar Alto. Goal of the observations is to kinematically verify the membership of these candidates, thereby getting a list of secure members in the outer part of Draco. Higher resolution spectroscopy of these members will then yield the profile of the velocity dispersion in Draco. The data are not analyzed yet. (Odenkirchen, Grebel)

With new data from the SDSS, the spatial structure of the Sextans dwarf galaxy was investigated and its characteristic parameters were determined (Odenkirchen, Harbeck, Grebel). The stars on the giant branch and on the red horizontal branch of Sextans are forming an elliptical distribution with an axis ratio of 1:1.5. The radial profile of the surface number density is described by a King model (W_0 = 4.8, r_c = 16.7’) and by extrapolation to zero surface density yields a boundary radius of about 160’ or 4 kpc. Thus, Sextans turns out to be significantly more extended than the Draco dwarf galaxy located at a similar galactocentric distance. But neither Sextans nor Draco shows evidence of perturbations caused by tidal forces. A study of the distribution of the blue and red horizontal-branch stars in Sextans shows the red horizontal-branch stars being more strongly concentrated towards the center than the blue ones.

6.5.7 Spectral Library with SDSS Resolution

D. Harbeck and E.K. Grebel took integrated spectra of globular clusters and young star clusters in the Large Magellanic Cloud using the 2.2-m telescope on Calar Alto and the ESO 1.5-m telescope. The goal is to establish a library of spectra of populations with known ages and metallicities which have the same resolution and cover the same wavelength range as SDSS. Such a library is planned to be used later for interpretation of galaxy spectra in the SDSS data base.

6.5.8 Tests of the Photometric Quality of the SDSS

E. K. Grebel, together with J. Holtzman (New Mexico State University, USA), D. Harbeck, and M. Odenkirchen, tested the photometric quality of the first public SDSS data set (Early Data Release, EDR). We determined the transformation equations between Johnson-UBVRI photometry and the photometric system of the SDSS by comparison with Landolt-standard-fields. The SDSS photometry, it turned out, shows larger uncertainties than was aimed at in the project. The causes for this are currently investigated by the SDSS collaboration.

6.6 Theoretical Work

6.6.1 Cosmology/Dark Halos

Within the scope of his PhD thesis, S. Khochfar, together with A. Burkert, calculated semi-analytical models of galaxy formation to study morphological properties of elliptical galaxies. The technique is based on the Press-Schechter formalism, which allows tracking of the merger history of dark-matter halos. It has been used to predict the abundance of disky and boxy ellipticals assuming that they are created in 3:1 and 1:1 mergers, respectively. A sophisticated semi-analytical approach including gas physics and star formation will be tested against observations of galaxy evolution. Within the scope of his PhD thesis, H. Hetznecker, together with A. Burkert, worked on the formation history of dense cores in dark halos. Using cosmological *N*-body simulations carried out with the special GRAPE hardware, he investigated the effects of locally restricted modifications in the initial cosmological conditions on the structure of dark halos at $z = 0$. Matter residing within the controversially discussed halo centers always originates from primordial regions with locally maximum densities, regardless of the individual formation and merger history of the halo. In particular, the process of ‘‘violent relaxation’’ prevents an isothermal structure being imposed on the dense, singular cores of the halos by any manipulation of the initial conditions. This – by no means new – ‘‘cusp problem’’ is in disagreement with many observations which indicate a flat density run in the centers of the halos.

R. Jesseit, in collaboration with A. Burkert and T. Naab, investigated through numerical simulations how a forming galaxy influences its surrounding dark halo. If the galaxy is forming slowly enough, then the subsequent contraction of its dark halo can be described by a simple analytical formula first devised by Blumenthal et al. (1986). *N*-body simulations confirm the validity of the analytical approximation for a wide range of galactic potentials and formation time scales. Contracted halo-disk systems were used to test a problem typical for CDM cosmologies. Observations of dwarf galaxies revealed that their dark matter halos have a constant density core, contrary to what is found in high-resolution cosmological *N*-body simulations (e.g. Navarro, Frenk and White 1997). Navarro, Eke and Frenk (1996) suggested resolving this conflict by a sudden loss of a large part of the baryonic matter, i.e. a starburst, which might modify the center of the dark halo significantly. However, our simulations show that for reasonable models of galactic disks it is not possible to remove enough material from the center as to resolve this problem genuine to CDM cosmologies.

6.6.2 Galaxies

Adrainne Slyz worked on two projects concerning galactic disks. In collaboration with A. Burkert, J. Silk, and J. Derivend, she investigated whether an equivalence between the viscous and star-formation timescales in galactic disks could be responsible for their exponential stellar profiles. In collaboration with H.-W. Rix and T. Kranz, she probed the stellar and dark mass fractions of several spiral galaxies by comparing their observed velocity fields and the velocity fields obtained through hydrodynamical simulations.

C. Travaglio, in collaboration with C. Abia (University of Granada, Spain), A. Burkert, M. Busso (Perugia, Italy), D. Galli (Florence, Italy), R. Gallino (Turin, Italy), J. Lattanzio (Monash University, Australia), and S. Randich (Florence, Italy), investigated the evolution of light and heavy elements in the interstellar medium of our Galaxy. In particular, she focused on Lithium as well as on elements from Barium up to Lead and Bismuth that are produced by slow and rapid neutron capture nucleosynthesis. The evolution of the Lithium abundance and its main stellar sources are still not completely understood. In this study, she considered the interplay among the different stellar sources contributing to the Li abundance of PopI stars. Moreover, in order to put stringent constraints on theoretical models, she observed a selected sample of PopI stars, including field and evolved stars, and determined their Li abundances and metallicity.

She also developed a stochastic model for the early evolution of the galactic halo gas in order to follow the time variation of the dispersion of the abundance of heavy elements over 1 – 2 Gyr. She computed the abundances of typical products of r-process nucleosynthesis showing that, under standard assumptions about the IMF, the cloud mass spectrum etc., the observed spread of element abundances at low metallicities could be reproduced, in agreement with the prevailing idea that the scatter cannot solely be attributed to observational uncertainties.

To investigate the internal structure of simulated galaxies, T. Naab developed a numerical tool to analyze the two-dimensional line of sight velocity distribution. These data can be directly compared to observations of elliptical galaxies. In collaboration with A. Burkert, T. Naab worked on formation of elliptical galaxies by mergers of spiral galaxies. They found that the detailed kinematics of collisionless 3:1 merger remnants of spiral galaxies is in disagreement with observations of the kinematics of faint, massive elliptical galaxies. An additional stellar disk component is required to be consistent with the observations. If the progenitor galaxies were gas-rich, an extended gaseous disk might form in the merger remnants from the gas falling back from the tidal arms. If the progenitor galaxies were poor of gas, a disk might form from gas that was lost from stars after the merger.

Within the scope of his PhD thesis, M. Bertschik, under the supervision of A. Burkert, worked on numerical simulations of the effects of minor mergers on the structure of disk galaxies, i.e. the increase of the velocity dispersion of disk stars and modifications of the radial and vertical scale lengths of disk galaxies. Special attention was paid to the thick disk of the Milky Way Galaxy, to the distribution and kinematics of white dwarfs as well as to the modification of parameters of disk galaxies. In this study, evidence was found for the frequency of substructures in dark-matter halos. Among other things, it was shown that the Milky Way System has accreted about 10% of its mass in minor mergers within the past 6 billion years without significantly increasing the local velocity dispersion, i.e. determinable by observations. On the other hand, it was found that a minor merger of a mass ratio of 20% of the Galaxy's mass could be quite responsible for the discontinuity in the velocity dispersion of the thick disk. In addition, it was found that the kinematics of individual white dwarfs indicates a rather massive halo.

In collaboration with F. van den Bosch (MPA, Garching) and R. Swaters (Carnegie, Washington), A. Burkert investigated the angular momentum distribution of the visible gaseous and stellar components in low-mass spiral galaxies. This distribution, it turned out, is in disagreement with the predictions of cosmological models. It might be explained by an early heating period during galaxy formation which decoupled the dynamics of the gas from the dark matter.

In collaboration with J. Silk (Oxford), A. Burkert developed a model to explain the good correlation between the masses of central black holes in elliptical galaxies and the latter's stellar velocity dispersions. According to this model, the correlation is a result of two competing processes: star formation and gas accretion onto the central black hole.

A. Burkert, together with E. Ardi (ARI), investigated the heating of galactic disks by dark halos of cosmological substructures. He showed that low-mass substructures do not have a significant effect on the scale heights of the disks.

A. Burkert, together with F. Prada, investigated the fraction of dark matter in satellite galaxies. The observations show a very strong correlation between the metallicity and the mass/luminosity ratio of these objects, which gives a deep insight into their chemical evolution but is not understood in detail.

7 CONFERENCES, LITERATURE, MISCELLANEOUS

Grebel and Geisler (Conceptión, Chile) organized the IAU Symposium 207 on ''Extragalactic Star Clusters'' with about 180 participants in Pucón, Chile (March).

From April 3 – 5, the ''First DIVA Thinkshop'' took place.

In May, the 15th Calar Alto Colloquium took place in Heidelberg with 20 short talks.

Grebel organized a workshop on ''The Lowest Mass Galaxies and Constraints on Dark Matter'' with about 60 participants, which took place on Ringberg Castle (end of July/ beginning of August).

25 visitor groups with a total of 450 participants were given a tour of the Institute in Heidelberg. (Quetz, Lang et al.)

On Calar Alto, 1274 visitors (75% of whom were Spanish school children and 10% of Spanish public organizations and institutions) were given a tour of the observatory. (J. Capel et al.)

The independent Annual Report of the Institute for 2000 appeared in both German and English (Staude, Quetz; Th. Bührke)

As senior editor, Staude, assisted by Neckel and Quetz, organized the 40th volume of the journal ‘‘Sterne und Weltraum’’.

7.1 Participation in Committees

C.A.T. Bailer-Jones: Member of the ESA GAIA Science Team; chairman of the GAIA ‘‘Classification Working Group’’; member of the DIVA photometry and spectroscopy working group; member of the Scientific Organizing Committee of the conference on ‘‘Census of the Galaxy: Challenges for photometry and spectrometry with GAIA’’.

E.K. Grebel: Referee for applications to the Canadian Program Committee for the Gemini Telescopes; member of the Student Committee at MPIA; member of the PhD Advisory Council (PAC) at MPIA; representative of MPIA in the Collaboration Council of the Sloan Digital Sky Survey; Women’s Representative; deputy member of the board of the Scientific Ernst-Patzer Foundation.

R. Gredel: Member of the Calar Alto Program Committee; member of the OPTICON working group ‘‘Future of Medium-sized Telescopes’’.

U. Klaas: Member of the ISO Post Operations Coordination Committee; co-investigator of the HERSCHEL-PACS consortium.

Ch. Leinert: Member of the appointment committee for the University of Jena for the C3 professorial position in Astrophysics; member of the ESO working group for preparation of the ‘‘Science Demonstration Time for the VLT’’; member of the ‘‘Working Group on Optical/IR interferometry’’ of the Division IX of the IAU.

K.-H. Marien: Member of the DIVA Co-investigator Team.

R. Mundt: Member of the Calar Alto Program Committee.

D. Lemke: Member of the ISO Science Team of ESA; co-investigator of the HERSCHEL-PACS consortium; co-investigator of NGST-MIRI; member of the refereeing committee ‘‘Verbundforschung Astronomie’’; MPIA coordinator of the POE network.

R.-R. Rohloff: Member of the Sloan Digital Sky Survey (SDSS) Review Committee (November, Fermilab, Chicago, USA).

H.-J. Röser: Secretary of the Calar Alto Program Committee; allocation of MPG-observing time at the 2.2-m telescope on La Silla.

7.2 Teaching Activities

Summer semester 2001:

U. Klaas: Ultra and Hyper-luminous Infrared Galaxies (lecture); D. Lemke: Astronomy and Astrophysics III (seminar); M. Stickel: Astrophysical Data Analysis (lecture); H.-J. Röser: Cosmological Test Observations (lecture); Ch. Leinert: History of Astronomy (seminar; co-supervisor).

Winter semester 2001/2002:

M. Haas: Physics III (group instruction); D. Lemke: Astronomy and Astrophysics III; H.-J. Röser (co-supervisor): Astronomy and Astrophysics III (seminar).

7.3 Lectures and Participation in International Events and Conferences

Workshop on ‘‘Dwarf Galaxies and Their Environment’’, Bad Honnef, January: E. K. Grebel (invited review lecture).

Seminar, University of Hertfordshire, England, January: L. Pentericci (invited lecture).

On the Origin of the World, Fachhochschule Regensburg, January: H.-W. Rix (lecture).

ISO Calibration Legacy Conference, Vilspa, Spain, February: P. Ábrahám (lecture).

ISO Calibration Legacy Conference, Vilspa, Spain, February: C. del Burgo (lecture, 2 posters).

Universidad Complutense de Madrid, Madrid, Spain, February: C. del Burgo (invited lectures).

American Association for the Advancement of Science, San Francisco, USA, February: E. K. Grebel (invited review lecture).

ISO Calibration Legacy Conference, Vilspa, Spain, February: P. Héraudeau (lecture, poster), U. Klaas (invited lecture), D. Lemke (invited lecture).

Massive Black Holes from $z = 0.001$ to $z = 4.5$, University of Cambridge, February: H.-W. Rix (invited lecture).

Massive Black Holes from $z = 0.001$ to $z = 4.5$, University of Oxford, February: H.-W. Rix (invited lecture).

Planets – an Inventory, Planetarium Berlin, WFS, February: A. M. Quetz (public lecture).

ISO Calibration Legacy Conference, Vilspa, Spain, February: K. Wilke (lecture).

The atmospheres of ultracool dwarfs, Carnegie Mellon University, Pittsburgh, PA, USA, March: C. A. T. Bailer-Jones.

Planets, Exoplanets and their Formation, Planetarium Wolfsburg, WFS, March: A. M. Quetz (public lecture).

Variability and rotation in ultracool dwarfs, Zentrum für Astronomie und Astrophysik, Technische Universität, Berlin, March: C. A. T. Bailer-Jones.

The Dark Universe, Baltimore, MA, USA, March: A. Burkert (invited lecture).

IAU Symposium 207 on ‘‘Extragalactic Star Clusters’’, Pucón, Chile, March: E. K. Grebel (invited review lecture).

SDSS Collaboration Meeting, Chicago, USA, March: E. K. Grebel (plenary lectures).

Astronomical Colloquium, University of Bonn and MPIfR, March: S. Jester (invited lecture).

Astronomische Großgeräte, Potsdam, March: D. Lemke.

SDSS General Collaboration Meeting, Chicago, USA, March/April: L. Pentericci.

IAU Symposium 207, Extragalactic Star Clusters, Pucón, Chile, March: A. Stolte (poster).

INAOE, Mexico, April: C. del Burgo (invited lecture).

Colloquium, University of Wisconsin, Madison, USA, April: E. K. Grebel.

Planetarium Stuttgart, April: E. K. Grebel (public lecture).

OPTICON Board Meeting, Catania, Italy, April: R. Gredel.

Mirror Maintenance Conference, Mt. Palomar Observatory, April: R. Gredel.

Infrarot-Kolloquium, Freiburg, April: R. Hofferbert (invited lecture).

First DIVA Thinkshop, MPIA, Heidelberg, April: K.-H. Marien.

ESO Workshop on “ The Origin of Stars and Planets”, Garching, April: A. Stolte (poster).

EBL Workshop, Helsinki, Finland, April: D. Lemke.

Black Holes at the Centers of Galaxies from $z > 4$, AIP, Potsdam, April: H-W. Rix (invited lecture).

Spectral classification in large, deep surveys using neural networks, Astronomisches Institut der Universität Basel, May: C. A. T. Bailer-Jones (invited lecture).

Modelling data: Analogies in neural networks, simulated annealing and genetic algorithms, conference “Model-based reasoning”, Pavia, Italy, May: C. A. T. Bailer- Jones.

Pupil’s Day Physicy at MPIA, May: A. M. Quetz, M. Bertschik, D. Harbeck, O. Krause, M. Wetzstein.

“Omega 2000: a new wide field near infrared camera for Calar Alto” and “Time-resolved photometric monitoring of brown dwarfs”, Calar Alto Colloquium, Heidelberg, May: C. A. T. Bailer-Jones.

Calar Alto Colloquium, Heidelberg, May: E. K. Grebel (lecture).

Seven lectures in schools and planetariums on recent results of astronomy, May to December: J. Staude.

GAIA conference “The termination of stellar parameters with GAIA”, ESTEC/ESA, Netherlands, June: C. A. T. Bailer-Jones (invited lecture).

Dark Matter, Annual Meeting of the Max-Planck-Society, Berlin, June: A. Burkert (invited lecture).

XVIIth IAP Colloquium on “Gaseous Matter in Galaxies and Intergalactic Space”, Paris, France, June: E. K. Grebel (invited review lecture).

IAU Colloquium “184 AGN Surveys”, Armenia, June: M. Haas (invited lecture).

Where’s The Matter? Tracing Dark and Bright Matter With The New Generation of Large-Scale Surveys, June: S. Khochfar.

Particle Astrophysics Workshop, Potsdam, June: D. Lemke (invited lecture).

Infrared and Submillimeter Space Astronomy-Colloquium, France, June: M. Stickel (invited lecture).

“Determination of stellar parameters with GAIA” at the conference “Census of the Galaxy: Challenges for photometry and spectrometry with GAIA”, Vilna, Lithuania, July: C. A. T. Bailer-Jones.

Workshop on “The Lowest-Mass Galaxies and Constraints on Dark Matter”, Ringberg Castle, July/August: E. K. Grebel (lectures).

Conference “Tracing Cosmic Evolution with Galaxy Clusters”, Sesto, South Tyrol, Italy, July: L. Pentericci.

“Galaxy Structure Research at the MPIA”, MPIA Hauskolloquium, Heidelberg, July: H-W.Rix.

“Galactic Nuclei: Is smaller more interesting?”, Symposium “The Lowest Mass Galaxies”, Ringerberg Castle, July: H-W Rix.

“Tracing Cosmic Evolution with Galaxy Clusters”, Sesto, South Tyrol, Italy: July: H.-J. Röser (poster).

“Cosmological Galaxy Formation and Dark Matter Halos”, Workshop, Santa Cruz, CA, USA, August: A. Burkert (invited lecture).

MPA/ESO/MPE/USM Joint Astronomy Conference: “Lighthouses of the Universe”, Garching, August: S. Jester (lecture).

Conference “Lighthouses of the Universe: The Most Luminous Celestial Objects and their use for Cosmology”, Garching, August: L. Pentericci.

Deutsche Schule und Rotary Club, Marbella, Spain, September: K. Birkle (public lecture).

“First UKAFF Conference”, Leicester, UK, September: A. Burkert (invited lecture).

Colloquium, Observatoire de Strasbourg, Strasburg, France, September: E. K. Grebel.

OPTICON Medium-sized Telescopes, Toulouse, France, September: R. Gredel.

OPTICON Board Meeting, Münic, September: R. Gredel.

9th ESMATS, Belgium, September: R. Hofferbert (invited lecture).

Workshop on Relativistic Jets, Ringberg Castle, September: S. Jester.

Colloquium, Astronomy & Astrophysics Department, University of Chicago, September: S. Jester.

Astronomy Colloquium, University of Minnesota, September: S. Jester (invited lecture).

Science Lunch Talk, MIT Center for Space Research, Cambridge, USA, September: S. Jester.

9th ESMATS; Belgium, September: O. Krause.

JENAM, Munich, September: C. Maier (poster).

Fall Meeting of the Astronomical Society, Munich, September: R. Mundt (poster).

Fall Meeting of the Astronomical Society, Munich, September: A. Stolte (poster).

“MIDI on the VLTI: interferometry at 10 μm”, Fall School: “Préparations des premières observations du VLTI”, Nice, 22 .– 4. October: Leinert.

Workshop “Elliptical Galaxies”, Ringberg Castle, November: A. Burkert (invited lecture).

Physics Colloquium und Seminar Lecture, University of Bochum, Bochum, November: E. K. Grebel.

Workshop “Formation & Evolution of Giant Elliptical Galaxies”, Ringberg Castle, November: U. Klaas (invited lecture).

“Disks of Galaxies: Kinematics, Dynamics and Perturbations”, Puebla, Mexico, November: T. Kranz (lecture).

Hochschultag, TFH Berlin, November: D. Lemke (festive lecture).

XIII Canary Islands Winter School of Astrophysics: “Cosmochemistry”, Puerto de la Cruz, Tenerife, November: C. Maier (poster).

DFG-Workshop on star formation, Bad Honnef, November: R. Mundt.

International Conference “Disks of Galaxies: Kinematics, Dynamics and Perturbations”, Puebla, Mexiko, November: H-W Rix (lecture).

“Gas vs. Stars, Jeans vs. Schwarzschild: The Pain and Gain of Detailed Dynamical Modeling”, Workshop, Ringberg Castle, November: H-W Rix (lecture).

Colloquium, Steward Observatory, University of Arizona, Tucson, December: E. K. Grebel.

ESO (Lunch Colloquium), Garching, December: U. Klaas (invited lecture).

7.4 Publications

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7.4.2 Diploma Theses

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