

Max-Planck-Institut für Astronomie Heidelberg, Germany

This report covers the period from January 1 to December 31, 1999 and is an abbreviation of the more detailed German version published in *Mitt. Astron. Ges.*, 2000.

1 STAFF

Directors: Appenzeller (acting Director), Beckwith (leave of absence), Rix (Director, from 1.1.).

Scientific staff: Abraham, Bailer-Jones, Beetz, Bianchi (from 1.11.), Birkle, Burkert, Dehnen (from 1.7.), Feldt (from 1.2.), Fried, Graser, Haas, Herbst, Hippelein, Huang (until 31.1.), Iбата (from 1.10.), Klaas, Kley (from 1.10.), Kümmel (from 1.2.), Leinert, Lemke, Lenzen, Ligor, MacLow (until 30.6.), Marien, Meisenheimer, Mundt, Neckel, Patsis (1.1.-30.9.), Radovich (until 14.9.), Röser, Schmid (1.4.-30.9.), Schmidtobreick (until 31.7.), Slyz, Staude, Stickel, Wilke (from 1.1.), R. Wolf, Zickgraf (1.2.-31.3.).

Scholarship holders: Barrado-Navascués (DFG), Berkefeld (until 30.11.), Cretton (from 1.9.), Mori (until 31.7.), Fockenbrock (until 30.4.), Heraudeau, Kessel (DFG), Kroupa (from 1.11.), Maciejewski (until 8.11.), Nelson, Porro (until 14.10.), Robberto (until 30.4.), Thiering, Woitas (from 1.11.) Chr. Wolf (SFB), Xu (from 1.2.).

Visiting scientists: Courteau, Victoria/Canada (Aug), Cretton, Leiden (Feb/Mar), Guivarch, Marseille (May), Hensler, Kiel (Nov/Dec), Hozumi, Japan (June), Jannuzi, Tucson (Jul/Aug), McIntosh, Tucson (Jul/Aug), Sarzi, Padova (from Aug), Steinmetz, Tucson (Jul/Aug), O'Dell, Houston (y), Salucci, Trieste (Oct), Shields, Athens/USA (Juni/Juli), Toth, Budapest (Jul/Aug), Travaglio, Florence (Feb-Nov), Yahagi, Tokyo (Jul/Aug), Zheng, Baltimore (Sept).

PhD students: Baumann, Eckardt (until 28.2.), Geyer (from 1.1.), Hartung (from 1.6.), Heitsch, Hetznecker, Hotzel, Jester, Kasper, Kranz, Lang (from 1.10.), Maier (from 1.10.), Naab, Phleps, Rudnik (24.5.-6.8.), Schuller, Seidel (until 30.4.), v. Kuhlmann, Weiss (from 1.6.), Woitas (until 31.8.).

Diploma students: Helfert (from 1.2.) Jesseit (from 1.2.), Khochfar (from 1.4.), Krause, Wackermann (until 30.9.), Wetzstein (from 1.12.). From the Fachhochschule Mannheim: Leborg (15.3.-14.9.), Lehmitz (until 31.3.), Müller (from 1.9.), Müller-Zumstein (1.3.-31.8.), Steckel (until 28.2.), Thomas (until 28.2.).

Regular ISOPHOT work conferences were held at the Institute throughout the year. These were attended by national and international co-investigators from both industry and other institutions. Thus, many other guests visited the Institute who are not individually listed here.

2 CALAR ALTO OBSERVATORY

From the beginning of the 1998 winter semester until the end of the summer semester 1999, observation time with the Institute's telescopes was distributed as shown in the following table: (columns 2 to 6: number of allocated nights; TEL:

telescope, MPIA: Max-Planck-Institut für Astronomie, SP: Spanish, RDS: German institutes other than MPIA, EX: institutes from other countries, TS: training, tests: DSAZ and ALFA).

2.1 Weather Statistics

In the winter semester 98 and summer semester 99, there was a total of 202 clear nights with six or more usable hours of darkness, with a total of 1954 clear night-hours suitable for observing. There were 112 photometric nights.

3 TELESCOPES

3.1 The 3.5 m Telescope

After the re-aluminizing of the 3.5 m mirror, the previous astigmatism was corrected by adjusting the axial support system. The setting of a "fixed point" outside of its working area was identified as the reason why the support system was not functioning correctly. (Henschke, Thiele, R. Wolf)

3.2 The 2.2 m Telescope

Another error found in the Coudé part of the telescope control program was identified as being the reason for the failure of the pointing corrections. Now that this error has been eliminated, the telescope functions as accurately in Coudé operation as it does in RC operation. (R. Wolf)

3.3 The 1.2 m Telescope

After exchanging the main mirror last year, the secondary mirror was replaced this year. This has considerably improved the optical quality. (Henschke, R. Wolf)

A new control desk was installed in the dome. The telescope and instrumentation are now operated from the observation room on the ground floor. Consequently, the observer only has to go to the telescope to switch it on and off and to open and close the dome. Dome tracking is automatic. (W. Müller, Thiele, R. Wolf)

4 INSTRUMENTATION DEVELOPMENTS, COMPUTING FACILITIES

4.1 Instruments for Calar Alto

4.1.1 LAICA: Large Area Imager for Calar Alto

Focal reducers such as CAFOS or MOSCA may have a relatively large field of view of approximately 11×11 square arcminutes, but many projects require a much larger field. The new LAICA project plans to build a wide-field camera with 67 108 864 pixels (approximately 8K square).

LAICA will be used at the prime focus of the 3.5 m telescope with the three-lens corrector. The instrument consists of three modules: shutter, filter module and CCD mosaic. The shutter is a slit shutter consisting of two curtains that enable the beam to be transmitted or cut off. Initial laboratory tests have shown that this will also enable exposure times of one second at an exposure homogeneity of approxi-

TABLE 1.

TEL	MPIA	SP	RDS	EX	TS
3.5m	101	39	39	146 ^a	55 ^b
2.2m	75	42	42	215	21
1.2m	0	0	43	236	32

^acontains 5 nights for the “ALFA Science Demonstration Program

^bcontains 27 test nights for ALFA

mately 0.1%. The filter module consists of a cartridge and a selector arm. The cartridge contains 20 filters which can be placed in the beam path by the selector arm.

The CCD mosaic forms the heart of the instrument. Four Lockheed-Martin CCDs are used with 4096 x 4096 pixels, each of 15 microns. As these CCDs cannot be abutted, they are arranged so that the separation between the CCDs is almost the length of the edge of a CCD. Thus, an individual exposure does not produce a continuous field; rather the gaps are filled with three further exposures. The overlap of the CCDs is approximately 30 arcseconds enabling control of astrometry and photometry. Experiences gained with previous photographic plates taken in K3 and optical calculations have shown that, even in the corners of the field, the image quality is better than 0.3 arcseconds. The image scale is 0.225 arcseconds per pixel. A set of four images covers a photographic continuous field of one square degree.

Each CCD is divided into four quadrants that are read out separately; thus readout should be completed in less than 1 to 2 minutes. Two further CCDs are arranged in the focal plane and are used for tracking purposes. They are operated in the frame transfer mode and thus do not require their own shutter. As two CCDs are used, image rotation can be corrected as early as in the exposure stage, since the whole camera can be rotated by a few degrees. It is still not clear whether this will be necessary.

If all delivery dates are maintained and no unexpected problems occur, first light is expected at the telescope in December 2000. For the latest information, visit <http://www.mpia-hd.mpg.de/LAICA>. (Fried, Baumeister, Briegel, Benesch, Grimm, Marien, Rohloff, Unser, Zimmermann)

4.1.2 OMEGA 2000: a New Wide-field Near-infrared Imager for Calar Alto

As successor to Omega Prime (in operation since 1996) and Omega Cass (1997), both of which are fitted with the 1024 x 1024 HgCdTe array HAWAII-1, work has started on the development of the Omega 2000 camera, which is to be fitted with the new large 2048 x 2048 pixel array HAWAII-2 (Rockwell Science Center, California). The camera will be designed exclusively for direct images in the prime focus of the 3.5 m telescope. The scale is 0.45"/pixel, and with 15'.4 x 15'.4, the image field is five times as large as that of Omega Prime. There will be 16 broad and narrow-band filters in the 0.8 μm to 2.5 μm region. First light is planned for September 2001. Omega 2000 will replace Omega Prime. Omega Cass will continue to be used for spectroscopy and high resolution direct images and with the ALFA adaptive optics system. (Bailer-Jones, Bizenberger)

4.1.3 ALFA: Adaptive Optics with a Laser for Astronomy

This last year, 1999, was both a very good and crucial year for the ALFA system. The first diffraction-limited images with the laser guide star were produced in June (see also <http://www.mpia-hd.mpg.de/ALFA>). Later, the “ALFA Science Demonstration Program” demonstrated and verified the scientific potential of ALFA. Although this was only achieved with natural stars, the results were outstanding. We continue to wait for corresponding results with the laser guide star. A repetition of the program, in somewhat modified form, is planned for the second half of 2000. The failure to attain the planned results with the laser is attributable to a pumping tube fault as well as a telescope fault lasting several nights. One half of one night that fulfilled all conditions for observations with the laser guide star was also dogged by technical problems with the adaptive optics.

During the course of the year, new control electronics for the deformable mirror were installed, and several mirrors on the optical bench were also re-coated.

In September, the new camera for measuring and compensating for the atmospheric tip-tilt turbulence was tested for the first time. The “System for Tip Removal with Avalanche Photodiodes” (STRAP) was temporarily installed in ALFA and initial performance and sensitivity measurements were carried out. The sensitivity of the photodiode operated in the Geiger mode is at least 1.5 magnitudes better than the CCD camera currently in use. An image improvement of 0''.55 at 00''.28 full width at half maximum (FWHM) is typical of the capabilities of the STRAP system under good seeing conditions.

In October, in collaboration with astronomers from Galway (Ireland), a LIDAR system that can be used to measure the sodium layer in the mesosphere was tested. It was revealed that the sodium layer reaches a maximum at a height of some 90 km. The LIDAR system should be permanently installed in ALFA in the year 2000. In addition to determining the sodium concentration in the mesosphere, the LIDAR system can also be used to determine the focal point of the laser guide star. (Hippler, Feldt, Kasper, Weiß, Aceituno, Helmling, Montoya, Bizenberger, Rohloff, Wagner)

4.1.4 CCD Systems

New Detectors for Calar Alto In April, a CCD from SITE with 2K x 4K pixels each of 15 μm was installed on MOSCA at the 3.5 m telescope and has since been functioning smoothly. The detector has a readout noise of 6.5 e⁻ and a saturation charge of 76,000 e⁻. It can be used between 350 nm and 1100 nm and, according to manufacturer's figures, has a quantum efficiency of 78% at 400 nm, 84% at 700 nm

and 22% at 1 micron. Furthermore, in August, the 1.23 m telescope on Calar Alto was the final telescope to be fitted with a SI-424 CCD from SITe. The detector has $2K \times 4K$ pixels at 24 m with a readout noise of $6.0 e^-$ and a saturation charge of 140,000 e^- . In August, Mike Lesser also delivered the last but one CCD from the joint Loral/Lesser project. It fulfils specifications similar to the defective LOR#8i, and was installed at CAFOS-2.2 in November. Its readout noise is $7 e^-$, and the saturation charge is 150,000 e^- . The quantum efficiency is 56% at 350 nm, 96% at 600 nm and 21% at 1 micron. (Figures from M. Lesser)

In November, the last of the $2K \times 2K$ CCDs from Loral was tested in the laboratory (LOR#13o). It has very good cosmetic quality and is to be exchanged at the next available opportunity for the LOR#11i on Calar Alto. As a result of CCD detector failures in recent years, new CCDs have only been installed on Calar Alto in cryostats with protective relay devices. In parallel to this, all other Calar Alto CCD Dewars should be fitted with such relay boxes by the end of 2000.

New CCDs at the MPIA In autumn 1999, the company EEV delivered CCD 44-82BI. The detector has $2K \times 2K$ pixels 15 m in size and a readout noise of $2 e^-$ (manufacturer's figures). After completion of the mechanical and electrical components for mounting and supplying the CCDs in the cryostat, use of the detector is planned for Spring 2000 on Calar Alto.

Further activities The planned large-field imager, LA-ICA, is to have its own dedicated tracking facility. CCD detectors in the LAICA cryostat are mounted at the edge of the science field in order to measure the deviation of a guide star. To do so, the CCDs have to be operated in the frame transfer mode, a mode of operation that was not previously supported by MPIA CCD control electronics. By simulating this mode of operation, it was possible to show that the ST-005A SITe detectors with 800×2000 pixels could be operated at 15 microns each in the frame transfer mode if the control electronics supplies a further set of vertical phases. The necessary modifications are currently being carried out.

In 1998, a CCD Dewar was mounted at the Twin spectrograph of the 3.5 m telescope. Its detector was mounted in a holder that, with the help of the three piezo motors, could be aligned precisely in situ in order to bring the CCD into the focus of the spectrograph. The disadvantage of this was that there was no display for the focal position. By fitting an encoder based on a Hall probe to each of the motors, it is now possible to set the focal position exactly and to make this adjustment reproducible. The retrofitting of the twin spectrograph with modified Dewars is planned for early summer 2000. Test measurements were carried out in August with MOSCA on the 3.5 m telescope in the nod-&-shuffle mode (AAO Newsletter, Nov. 98, p. 18). In this mode, simultaneous object spectra and background spectra in the same region of the CCD detector are taken and are thus subject to the same cosmetic effects on the CCD. In principle, the measurements produced the expected result, with two caveats. On the one hand, it was revealed that the detector used was not particularly suitable for this kind of measurement and, on the other hand, the setting range of the TV

guider was not designed to accommodate the nodding motion of the telescope. (Marien)

4.1.5 Clear Sky Monitor

For the automatic termination of operations and for closing the protective hut at sunrise or in the event of rain, a rain sensor and photo-electric lighting controller were installed in the system. A second computer and modified software enable the independent but simultaneous operation of the stellar and cloud cameras. (Beetz)

4.2 Instruments for Other Observatories

4.2.1 Wide Field Imager for the 2.2 m Telescope II on La Silla

As early as its first year of operation, the Wide Field Imager (WFI) at the 2.2 m telescope II on La Silla proved to be a tremendous success. On account of its optical quality and efficient CCD detectors, it quickly made a name for itself as the "world's best instrument of its kind." Consequently, at the deadline for applications on 1 October 1999, it was more difficult to obtain time with the WFI than it was with one of the VLT instruments.

The tremendous success of the WFI is due not least to the fact that the MPIA and ESO (Garching and La Silla) project groups quickly succeeded in eliminating those weaknesses that still existed at the time of the delivery in January 1999:

Filters: The initially very limited set of filters was completed in the year of this report. Since the beginning of 2000, there are six broadband filters (u_{SL} , B, V, R, I, z^+) and 25 medium-band filters (typically with $\Delta\lambda/\lambda = 3\%$) covering the wavelength region between 390 and 930 nm almost without gap. Four narrow-band filters that record the lines [OIII] λ 500.7 nm ($\Delta\lambda/\lambda = 1.4\%$ and 0.4%), H α ($\Delta\lambda/\lambda = 1\%$), and [SII] λ λ 672, 674 nm ($\Delta\lambda/\lambda = 1\%$) between $cz = 0$ and 2000 km s^{-1} enable investigations to be made of the Milky Way and nearby galaxies in the light of individual emission lines. While all standard filters were supplied by the MPIA, ESO will soon provide a broader U-band as well as a somewhat shorter wavelength I-band filter.

CCD mosaic: Similarly to other CCD cameras built by ESO, the WFI camera also displayed since its commissioning contamination of the CCD mosaic; this spread from the edge, especially at $\lambda < 500$ nm, and led to a considerable drop in the quantum efficiency. This problem was solved at the end of 1999 by baking out the CCD mosaic and eliminating its main origin (non-vacuum-compatible adhesive in the cryostat).

Shutter: The shutter originally built by the MPIA was only fully reliable at temperatures of $> 5^\circ \text{C}$ since it combined two materials with very different thermal expansion properties. In June 1999, a new shutter was fitted which uses only aluminum and materials with very similar thermal expansion coefficients. However, after cleaning the CCD mosaic, it was revealed that the right-angled edges of the black nylon end plate create scattered light from the sky and from bright stars approximately $1'$ outside the field of view. A new endplate with edges angled at some 20° eliminated this problem.

Image field rotation: In addition to unavoidable image field rotations (due to misalignment of the telescope or refraction), moderate offsets in right ascension ($\Delta\alpha \geq 2'$) can lead to dramatic rotations of the CCD mosaic with respect to N-S direction. At high (negative) declinations $\delta \leq 45$, it is, therefore, mandatory to restrict the total amplitude of the offsets which are needed to fill the gaps between the individual CCDs ($\Delta\alpha = 23''$) to a certain range. Corresponding offset patterns for various declination intervals were designed and made available to all observers. Nevertheless, the unavoidable image field rotations limit the exposure time to ≤ 1000 seconds.

Remaining problems: The maximum exposure time specified can be increased by a factor of two if, when controlling with the guiding CCD located some $20'$ from the center of the mosaic, the image rotation is eliminated via a pointing model. Corresponding control software is currently in preparation. Even after its use, the maximum useful exposure times of ≤ 2000 seconds for some of the narrow and medium-band filters will lead to images in the fast (standard) readout being limited not by the background but by detector noise ($\sim 5 e^-$ read-out noise). We shall continue to negotiate with ESO with regard to the use of a slower readout, as originally planned ($\leq 3 e^-$ RON at read-out times of approximately 200 seconds). Due to financial considerations and delivery problems, the CCD mosaic contains several individual CCDs that do not meet the "science grade" requirements and that are distinguished by a number of "warm" columns and pixel clusters. This is beyond our control. When taking several images of a field (such as are needed to fill the gaps), these defects can be easily corrected. However, in the case of applications that only use one or two images per field, particular care has to be taken.

During the commissioning of the WFI, the 2.2 m telescope demonstrated a strong, position-dependent astigmatism caused by the incorrect functioning of the main mirror support. ESO (La Silla) is currently making great efforts to find and eliminate the cause of the problem.

Data analysis: Two Sun Enterprise 450 workstations are available at the MPIA providing a total of more than 500 GByte disk space; these are used exclusively for the analysis of WFI data. In view of the fact that various work groups at the Institute have by now obtained about a terabyte of WFI (raw) data, this computer performance and storage capacity have to be used with careful planning in order to prevent a bottleneck of the data flow. The WFI project group at the Institute is currently developing a standard software package that should enable the evaluation of images with the WFI, which are taken in a standard mode (≥ 5 offsetted images per field and filter). The CCD mosaic is treated as a monolithic total detector that needs to take into account the position and orientation of the individual CCDs in a global co-ordination system. Particular emphasis is placed on the optimum correction of defects and artefacts generated by cosmic radiation. This software will soon be available to all WFI users at the MPIA. (Meisenheimer, Böhm, Klein)

4.2.2 CONICA: High-resolution IR Camera for the VLT

In 1999, the infrared camera for the adaptive optics of the VLT was completed to the extent that the last InSb detector

(Aladdin) could be mounted and the final optical tests initiated. To this end, all modes of the instrument were subjected to an extensive initial optical and mechanical inspection. The control software was completed and the advanced observation software is currently being developed. The delivery to ESO is planned for April 2000. CONICA will then be handed over to the French consortium that is developing the adaptive optics. A first joint test is planned for July 2000. Contrary to the original planning, commissioning, together with the adaptive optics, is now planned at the UT3 telescope (Melipal) for March 2001. (Lenzen, Benesch, Fabian, Franke, Grimm, Hartung, Münch, Ortlieb, Rohloff, Salm, Storz, Wagner)

4.2.3 MIDI: Interferometry at the VLTI in the Mid-infrared

In 1999, the project underwent a phase of intensive consultations, which involved all areas of the design being frozen and work commencing on the production of the instrument. At the end of July, the Final Design Review for the optics was held at ESO and this was completed without any problems. The preparations for the Final Design Review for the remainder of the instrument took place at the end of the year, and this is planned for February 2000.

The design of the cold optics commenced at the partner institute, the NFRA in Dwingeloo, Netherlands. A prototype of the most critical mechanical part, the device for beam combination, was produced and tested. The precise positioning requirements of a few microns at this position were achieved. The design of the warm part of the optics was completed and adapted to the changed conditions in the interferometric laboratory on Paranal (with O. von der Lühe, Kiepenheuer-Institut für Sonnenphysik, Freiburg).

Investigations were performed on the piezo motors responsible for the adjustment of internal path length. Speed, stability and accuracy either met or exceeded the required values. The specifications for the most sensitive optical part of the instrument, the beam combiner, were verified by tests of the thermal properties of the AR coatings developed. The company Präzisionsoptik Gera was commissioned to perform the work.

Raytheon was commissioned to manufacture the detector (Si:As IBC size 320×240 pixels). A first test model has already been delivered. By the end of the year, work on the electronics for detector read-out reached the point where, on a bare multiplexer, a projected light pattern was recognizable in the image read out. Good progress was made with regard to detector control and readout programming within the complex environment for the VLT.

A cryostat with similar dimensions to the final instrument was produced in order to investigate temperature properties and vibrational sensitivity, and to allow the necessary corrections to be integrated into the design of the actual cryostat. This final cryostat was designed and adjusted to the design for the cold optics that it will later house. The calibration sources for laboratory tests are currently being set up. Large-scale work has started on the instrument software; the main responsibility for this, and for co-ordination, lies with the Sterrewacht Leiden (W. Jaffe). An important part of the de-

sign work was to determine the suitable data format, previously not supported on Paranal, the so-called “binary table FITS”, within the scope of discussions with ESO. In Heidelberg, work commenced on the control of the instrument functions as part of the VLTI environment already mentioned. The electronics for this were designed and in part completed and tested. The necessary computers and additional equipment for operating the instrument were purchased or provided by ESO for development. It is planned to test the instrument in Heidelberg and ship to Paranal in late autumn 2001. (Leinert, Graser, Grimm, Hippler, Laun, Lebong, Lenzen, Ligori, Mathar, Ortlieb, Pitz, Porro, Rohloff, Salm, Schuller, Storz, Wagner)

4.2.4 LINC, the Near-infrared Beam Combiner for the LBT

As one of the MPIA contributions to the Large Binocular Telescope project, we proposed designing and building an interferometric beam combiner for the near-infrared spectral region. This instrument, called LINC, will also use the unique high-spatial resolution properties of the LBT for very weak sources within a large field of view. More specific work on LINC commenced in the year of this report with the appointment of post-doc, Marc Ollivier. The first task was to adapt commercial software to the design and optimization of LINC. (Herbst, Ollivier, Rix, Bizenberger, Rohloff)

4.2.5 LUCIFER, a NIR Spectrograph and Camera for the LBT

In collaboration with the MPE, the Landessternwarte Heidelberg, the University of Bochum, and the Fachhochschule für Technik und Gestaltung Mannheim, work started on the development of a powerful NIR imager spectrometer instrument for the LBT. (Bizenberger, Herbst, Lenzen)

4.3 Data Processing and Instruments for Satellite Astronomy

4.3.1 The ISOPHOT Data Center

In the second year after completion of observations with ISO, the program development and calibration analysis for version 8 of the automatic data analysis (off-line processing OLP V8.4) was completed. By processing representative test cases, progress as compared to “Pipeline V7” was checked thoroughly.

The new version resulted in further improvements to the photometric calibration, especially for weak sources whose flux represent only a small fraction of the sky background. The absolute and relative accuracy for chopped point-source measurements was also increased with the PHT-S spectrometer, for which some $\pm 10\%$ have now been achieved. The same accuracy was obtained for the absolute calibration of the surface brightness measurements with PHT-S. The main objective of the development of the OLP V8.4 was to improve the chopped photometry which, with some 3000 observations, makes for some 20% of all ISOPHOT measurements. It was possible to achieve a clearly more robust signal processing as well as improved calibration. In the case of weak sources, however, adjustments are necessary to elimi-

nate the chopper offset. In addition, the calibration accuracies for raster charts were determined with the FIR arrays (PHT-C), leading to the scientific qualification of a further 2,500 observations. Furthermore, the conformity of the absolute surface luminosities of ISOPHOT charts was checked with those of COBE/DIRBE photometry. With the limitation that, due to the very different fields of view (0.7 degrees for COBE as opposed to 3 arcminutes for ISOPHOT) most charts created with ISOPHOT are smaller than one pixel of those created with COBE, an agreement of greater than 25% was found.

The ISOPHOT Data Center made a number of suggestions for improving the ISOPHOT data representation in the archive. Thus, during the course of 1999, two improved versions of the central ISO data archive in VILSPA were introduced. Version 2, created in July, enabled access to instrument-specific parameters for improved instrument calibration. Version 3, created in December, enables the link-up of ISO observations to publications in specialist journals and IRAS data products, as well as extended possibilities for graphic representation of the archive products. The ISOPHOT Data Center in Heidelberg received some 50 visitors in 1999. DLR support of the data center until the end of 2001 was confirmed after a half-time review of the data center activities.

The photometric calibration of the serendipity survey at 170 μm was completed. This was achieved by comparing the signal strengths in the randomly-traversed calibration sources (integration time 1 s) with point calibration measurements on these sources. With the completion of photometric calibration, it was possible to compile the first galaxy catalogue of 115 sources with the best signal/noise ratios. (Lemke, Abraham, Bianchi, Haas, Héraudeau, Hotzel, Klaas, Radovich, Schmidtbreick, Stickel, Tóth)

4.3.2 PACS –Infrared Camera for the FIRST Satellite Observatory

The Institute made several contributions to the development of PACS. The cable harness concept between the helium-cooled focal plane unit (FPU) and the warm electronics was developed. The cable harness, consisting of over 600 individual cables, has to permit both the interference-free transfer of weak signals from the interior of the flight cryostat, as well as guarantee minimum thermal input in order to be economical with the liquid helium supply. The electrical networks within the FPU were also designed.

Various prototypes of the cold readout electronics, consisting of integrating preamplifiers with a large dynamic range and multiplexers, developed on the basis of CMOS electric circuits, were characterized in detail at the Institute. In the case of the tests at 4K, it was revealed that the amplification was too low, and this would lead to undesirable changes to the bias voltage at the Ge:Ga photoconductor detectors. Plans were drawn up for improvement during several advisory group meetings with employees of the MPE and the manufacturing company, IMEC.

The development of the focal plane chopper led to a prototype that essentially fulfils the PACS specifications. To achieve this, it was necessary to use a computer program

(originally written for the development of particle accelerators) for the thorough simulation of the drive. Materials and components were optimized for use at $T \sim 4$ K. In the case of rectangular chopping at ± 4 degrees with 10 Hz, the loss in heat dissipation of the prototype II chopper is only 4 mW.

Three industrial tenders for building the chopper flight model (and for lifetime, qualification and flight replacement models) were obtained, evaluated and a contract prepared.

The MPIA participated in the detailed planning for setting up the ground segment for FIRST and for the PACS control center (ICC) in particular. Based on experience with ISO, it was possible to make essential contributions to the design of a flexible control system that comprises both astronomical observations as well as calibration measurements and technical procedures. It was determined that the MPIA shall assume responsibility for co-ordinating all aspects of the in-flight instrument calibration for PACS.

The financing application in support of the contributions of the MPIA to PACS was generally approved by the DLR. The MPE Garching, which is leading the instrument development has submitted a draft of a memorandum of understanding that gives the MPIA a proportion of some $\sim 18\%$. (Lemke, Grözinger, Klaas, Krause, Rohloff, Böhm)

4.3.3 PRIME: a Survey Satellite for the NIR in Preparation for the NGST

The MPIA is participating in a proposal for a satellite experiment that is currently being prepared by the Johns Hopkins University in Baltimore as part of the SMEX program offered by NASA. A satellite for sampling in the NIR is planned; this is to map a large part of the sky in the 0.9 to 3.4 μm range up to a depth of 24.5 mag. A 75 cm telescope is to be placed in a circular, polar earth orbit at a height of 650 km and synchronized with the sun. The focal plane of a modified Paul-Baker telescope is divided over three dichroic mirrors into four wavelength channels that are fitted with newly-developed 2K x 2K arrays. In pointed 150 s integrations, a quarter of the whole sky is to be covered over a three-year period. In comparison with 2MASS, the currently most sensitive NIR survey, an increase in sensitivity by a factor of 1000 is to be expected, a considerable step for the investigation of the very early universe.

Thus, PRIME will deliver essential new data in practically all areas of modern astronomy: PRIME will find at least 1,000 type-Ia supernovae in the $1 < z < 5$ region and measure their light curves; all quasars in the field up to $z = 25$ will be found, this corresponds to an age of 1-2% of the total age; all protogalaxies in the scanned sky region up to $z = 20$ will be found; galaxy clusters up to $z \approx 10$ will be measured; the large-scale structures of dark matter up to $z \approx 3$ will be mapped; hundreds of brown dwarfs up to a distance of 1000 parsec will be found; free-floating Jupiter-sized planets can be verified up to a distance of 50 parsec; thousands of Kuiper belt objects in the outer solar system will be found. Should the proposal be adopted by NASA's SMEX program, phase A can commence in summer 2000. Launch is planned for spring 2004. (Lemke, Lenzen, Rix)

4.4 Computer Facilities

4.4.1 Computers and Network

Both the ground floor and the north wing were equipped with powerful switches (summit48 from Extreme Networks). Thus it was possible to convert the complete MPIA cabling to twisted pair. All laboratories and work rooms in the north wing now have 100 MBit at each workplace. By fitting the same switch in the Astro-Labor, here, too, each workstation has 100 Mbit. The connection to this building was achieved with a 1 GB glass-fibre cable. Additionally, a new Cisco router was installed in the Astro-Labor, thus the connection to the HD net is now also possible with 100 MBit.

In September, the central computer room was moved to the former photo laboratory. After the installation of air-conditioning, printers and server were put into operation in the new room. In this context, the computers crucial for safeguarding against power cuts were connected via UPS (uninterruptible power supply) facilities. The move took place without any major disturbance to computer operation.

The need for greater computer capacity for the CADIS and WFI projects was met with the purchase of two additional Enterprise 450 servers from Sun Microsystems. Each contains approximately 300 GB internal disk storage.

A PC cluster with eight double-processor systems was purchased for the theory group, and these are operated in parallel under Suse Linux 6.3. In this way, in addition to Origin 2000 that was also extended by eight processors, it was possible to provide the theory group with additional parallel computer capacity at an economical price. Test runs with four PCs have revealed that, with eight processors operating in parallel, it was possible to achieve almost 70% of the Origin performance.

The number of Linux computers has since increased to 16 systems. Consequently, starting in 2000, Linux administration will be centralized.

Before the end of the year 1999, the Y2K compliant Solaris 7 operating system was installed on all scientific workstations. No abnormalities occurred at the Y2K changeover. (Hiller, Rauh, Tremmel)

5 GALACTIC ASTRONOMY

5.1 Young Stars, Interstellar Matter

5.1.1 Cool Dwarf Stars

Work on the nearby triple star LHS 1070 continued and was concentrated on establishing the relative orbit for the dynamic determination of the masses of the two very low-mass companions. (Leinert, Woitas; Jahreiss, ARI, Heidelberg)

Based on 20 new speckle interferometric measurements, the relative astrometry since 1990 and an additional HST observation, we performed an improved orbit determination for the visual pair in the M-dwarf triple system, Gliese 866, and calculated the system mass at $0.34 M_{\odot}$. Together with the mass-luminosity relationship for low-mass main-sequence stars (Henry and McCarthy 1993) and plausible assumptions about the luminosity of the (unresolved) spectroscopic companion, we assessed the masses of the compo-

nents and find that all three stars have masses just above the stellar/substellar limits. Thus, despite its very low overall mass, the system does not contain a substellar object. (Woitast, Leinert; Jahrei, ARI, Heidelberg; Henry, CfA; Franz, Wasserman, Lowell Observatory, Flagstaff)

5.1.2 Extrasolar Planets, Brown Dwarfs and Low-mass Stars

Deep optical and infrared photometry of the young (~ 5 million years) cluster, Sigma Orionis, was performed by C.A.L. Bailer-Jones, D. Barrado y Navascués und R. Mundt, in collaboration with R. Rebolo, M. R. Zapatero-Osorio and V. Béjar (IAC, Tenerife). They also discovered a few dozen candidates with masses clearly below the substellar limit mass of $0.075 M_{\odot}$. Comparison with theoretical isochrones indicates that some of these objects have masses in the $5\text{--}13 M_{\text{jupiter}}$ region. As the limiting mass for deuterium combustion is about $13 M_{\text{jupiter}}$, they can be regarded as free-floating giant planets. The working group is in the process of confirming the properties and nature of these objects with the help of low-resolution spectroscopy.

C. A. L. Bailer-Jones, D. Barrado y Navascués and R. Mundt, in collaboration with R. Rebolo, M. R. Zapatero-Osorio and V. Béjar (IAC, Tenerife) as well as J. Eisloffel (Tautenburg), carried out a series of observations to search young open clusters for brown dwarfs. One of the main objectives of this project was to tackle the problem of the formation and development of these very low-mass objects. It is still not clear, for example, whether brown dwarfs form as a result of fragmentation, as assumed for hydrogen-burning stars. The atmospheres of brown dwarfs have very low temperatures (< 3000 K), so a more detailed investigation of these objects is interesting in view of the chemistry and physics of their atmospheres.

The work group selected five clusters for their investigation: Sigma Orionis (age 1–5 million years), IC 2391 (50 million years), IC 4665 (50 million years), the Pleiades (125 million years) and the Hyades (600–900 million years). Deep images in the optical (usually in the I- and Z-band) and/or in the near infrared (J-band) were obtained in each cluster over a large area. In the case of IC 2391, an area of 9 square degrees was covered in order to investigate the spatial distribution of brown dwarfs. The data for IC 2391 and the Hyades were mainly obtained with the new Wide Field Imager (WFI); this instrument was built by the MPIA and ESO and has been mounted on the 2.2 m telescope on La Silla in Chile since the end of 1998. For the first four clusters, as deep images as possible were taken with typical $5\text{--}\sigma$ detection limits of 22.5–25 mag in I that, in the youngest cluster, Sigma Orionis, enables the detection of objects with less than $10 M_{\text{jupiter}}$ (provided that the theoretical flows are correct).

Follow-up observations of possible brown dwarfs and low-mass stars in the open stellar cluster IC 4665 were made. With the help of MOSCA at the 3.5 m telescope and with FORS at the VLT, spectra were taken of approximately 350 objects. These objects were selected on the basis of their positions in the color-luminosity diagram (I – Z, Z). These investigations serve to determine, among other things, the

original mass function in the substellar region ($M \leq 0.07 M_{\odot}$), as well as an independent age determination of the cluster by means of the limiting mass, at which Li is already extensively burnt in the interior of the star. (Mundt, Barrado y Navascués, Bailer-Jones; Eisloffel, Thüringer Landessternwarte)

A program was started to search for brown dwarfs and low-mass stars in the near southern star-formation regions. To this end, CCD images were taken in the star-formation regions in Chameleon, Lupus and Corona Australis in various filters with the WFI at the MPG/ESO 2.2 m telescope. Most WFI images were obtained in the Chameleon dark-cloud region. Work has started on the analysis of the data obtained. (Mundt, Bailer-Jones; Eisloffel, López Marti, Thüringer Landessternwarte)

C. A. L. Bailer-Jones and R. Mundt began a program for monitoring the variability of brown dwarfs and L-dwarfs using the differential I-band photometry. During the course of two observing runs in 1999 (more of which are to follow in 2000), eleven objects were observed with the 2.2 m telescope on Calar Alto. The data from the January run, which is now published, revealed variability in the luminosity of the L1.5 dwarf 2M1145. Approximate value of the upper limits for the periods and amplitudes of five further objects were also published. 2M1145 is either a greater-mass brown dwarf ($0.065 \leq M/M_{\odot} \leq 0.075$) or a very low-mass hydrogen-burning star. The question remains as to what causes this variability. We are presumably dealing with a rotation modulation of surface features, but what are these features? Magnetically-generated stellar spots could be one possibility, although many rapidly rotating cool dwarfs demonstrate only a very low level of chromospheric activity. L-dwarfs are very cool ($1500 \text{ K} < T_{\text{eff}} < 2000 \text{ K}$) and it is known that dust forms in these objects. This dust possibly forms clouds in the atmosphere, so that the observed variability would be attributable to “weather” in the star atmosphere. Follow-up investigations are planned for the year 2000 in order to ascertain which of these possibilities is the correct explanation.

A program was started for the investigation of the variability of brown dwarfs in the open stellar cluster IC 4665. This investigation is based on data obtained in June 1999 with the WFI at the MPG/ESO 2.2 m telescope. The data were obtained over a two-week period, and the observations were carried out with very dense sampling in two nights in particular. Because periods in the 5–10 hours region are expected, most periods should be well recorded with this sampling. A preliminary analysis of the data revealed that, at $I \sim 19$, variations of a few times 0.01 mag could still be verified. (Mundt; Eisloffel, Scholz, Thüringer Landessternwarte)

In collaboration with J. R. Stauffer (CfA), J. Bouvier (Grenoble) and R. Jeffries (Keele, UK), D. Barrado y Navascués sampled several young open clusters (Alpha Per, IC 2391, M 35, IC 2547) in both the optical and the infrared regions. They discovered a large number of low-mass objects for each, both stellar and substellar, which possibly belong to the cluster. Some of these candidates were then investigated spectroscopically with the Keck/LRIS and the 4 m CTIO. For a few of them, it was possible to confirm that they did belong to the group and the lithium depletion boundary

(LDB) was localized in some of these clusters. It was possible to ascertain the age of these clusters using theoretical models and the LDB.

So far, the group has determined new age data for three young open clusters (IC 2391, Alpha Per and the Pleiades) and a new upper limit (IC 2547), so that a new age scale could be defined for young open clusters. The relationship between standard age and LDB age is almost constant (~ 0.66): this phenomenon enables us to conclude that, in the case of massive stars, an overshoot of the convective core is required and its value is not strongly dependent on mass.

T. Herbst, D.J. Thompson, R. Fockenbrock and H.-W. Rix, as well as S.V.W. Beckwith (STScI, Baltimore), continued their sensitive wide-field sampling for very cool brown dwarfs in the solar environment using the infrared cameras Omega-Prime and Omega-Cass. New J-band wide-field images, combined with R-band observations already in existence, enable a useful identification of brown dwarf candidates due to their extreme (R-J) colors. Follow-up measurements with specific filters can then confirm objects with methane absorption. The work group sampled a total area of 11.4 square degrees to $J = 20.5$ mag and $R = 25$ mag. Follow-up observations of promising candidates with CH_4 filters in a quarter of these fields did not reveal any methane-absorbing brown dwarfs. This indicates, with a 90% certainty, that the spatial density of objects similar to G1229b is less than 0.012 per cubic parsec. These estimates take the vertical structure of the galaxy into consideration, which can be important with sensitive measurements. Combining published theoretical atmosphere models with the observations of the group allows an upper limit of $\alpha \leq 0.8$ to be established for the exponents of exponential initial mass functions in this area.

5.1.3 Young Double Stars

Mass is a fundamental parameter of stars. This parameter can only be determined for spatially resolved double stars or eclipsing binaries, where the radial velocities of both components are measurable (SB2 systems). In the case of pre-main sequence stars, the mass was previously determined from the position of the stars in the theoretically-calculated Hertzsprung-Russell diagrams. A direct mass determination of young stars via as large as possible a mass and age region would enable us to test the development models of young stars for the first time. In a few years' time, with the help of the VLT interferometer, it will be possible to spatially resolve young double stars with periods of ≥ 100 days in nearby star formation regions ($d \sim 150$ pc) in the K-band. The inclination of many SB2 systems can be determined in this way. Since only one eclipsing SB2 system with relatively large-mass pre-main sequence stars (1.6 and $3.2 M_{\odot}$) has been found to date, and as only very few SB2 systems with periods of more than 30 days are known, we have started an in-depth search for spectroscopic double stars. As part of this sampling, some 250 young stars were again examined by spectroscopy with ESO's 1.5 m telescope (with FEROS) and the 2 m telescope of the Thüringer Landessternwarte.

As the candidates for long-period, spectroscopic double

stars ($P \geq 100$ d) are found on the basis of the radial velocity variations (RV variations), the stability of their photospheric lines was first investigated. It was determined that the stellar activity of young stars causes RV variations with (semi) amplitudes of some 2 km/s. In the case of some 8% of stars investigated, we found such large RV variations that we suspect we are dealing with long-period, spectroscopic double stars. This frequency of occurrence agrees well with that of the measured frequency of occurrence of young double stars. As expected, we also found some SB2 systems with short periods ($P \leq 10$ d), and we can now search these systems for eclipses. (Mundt, Leinert; Guenther, Thüringer Landessternwarte; R. Neuhäuser, V. Joergens, M. Fernández, MPIE; Batalha, Observatório Nacional, Rio de Janeiro; Vijapurkar, IUCAA, Pune, India; G. Torres; CFA)

The PhD thesis of J. Woitas presents the results of a series of two-dimensional speckle interferometric observations on Calar Alto (3.5 m telescope) and on La Silla (NTT) obtained in the years 1993 to 1998. We propose spatially resolved near-infrared photometry (JHK) for the components of 58 young double-star systems in the T and AB associations Taurus-Auriga, Scorpius-Centaurus, Chameleon and Lupus. We can thus enter the components in a two-color diagram and, in this way, identify unusually red objects that are candidates for infrared companions or young brown dwarfs. It is shown that such objects do not occur frequently. This is further confirmation of the observed frequency of double stars in these star-formation regions. (Leinert et al. 1993; Ghez et al. 1997, Köhler et al. 2000).

We enter the components of 17 systems from so-called weak-lined T Tauri stars (WTTS, for these stars, the influence of circumstellar excess emission on the measured colors can be neglected) in a color luminosity or HR diagram. By comparison with theoretical pre-main sequence evolution tracks, we can show that in almost all of these systems, within the range of their errors, the components are of the same age.

We enter the components into the HR diagram by taking their J-luminosity (at $\lambda = 1.25 \mu\text{m}$) as an indicator of their stellar luminosity, allocating the known spectral type of the system of the main components and working on the assumption, which has already been verified, that all components are of the same age. By comparison with theoretical models of pre-main sequence evolution, we then determine their masses. This reveals some components to be candidate substellar mass companions. The distribution of the mass ratios in the systems does not increase to $M_2/M_1 = 1$, nor is it dependent on either the mass of the main component or on the projected separation. This indicates that, during the protostellar collapse, fragmentation is the determining process of the formation of multiple-star systems, and the masses of the components are mainly determined by the fragmentation itself and not by the accretion process.

With the help of the relative astrometry of the components of close systems at various epochs, we show orbital movement in the majority of these systems and use this for a purely empirical estimate of an average mass of T Tauri stars; this is larger than the value obtained from the HR

diagram for the same systems. (Woitas, Leinert; Köhler, Potsdam)

Lunar occultation observations last year showed that, in the young double-star system Haro 6-37, a third component is present some $0''.3$ from the main star which can thus be observed with direct methods (speckle, adaptive optics). The two brighter components in particular are very variable. During a second observation on 3 September 1999, we also tried to detect the scattered light from the mm observations of opened circumstellar shells, but the conditions, and thus the accuracy of the measurements, were insufficient for this difficult detection. (Leinert, Woitas; Richichi, Arcetri).

M. Kasper and T. Herbst took spectra in the H and K band with an integral field unit of the central arcsecond of the T Tauri multiple-star system, using 3D spectrographs coupled to the adaptive optics system, ALFA. This instrument combination produced excellent spectral and spatial resolution (e.g. $R = 2000$, with 0.15 arcsecond-sized pixels at $2.2 \mu\text{m}$) which enabled us to unravel the various physical processes that take place in this complex region. The data have since been reduced and are currently being analyzed.

5.1.4 Rotation Periods of Young Stars

R. Mundt, C.A.L. Bailer-Jones, K. Meisenheimer, R. Wackermann and Chr. Wolf, in collaboration with W. Herbst (Wesleyan University), started an extensive program to investigate the evolution over time of the angular momentum of young stars. The presence of a circumstellar disk probably plays a decisive role in the final value of the angular momentum, which can be determined from the measured rotational period and the radius estimated from the luminosity. Stars with a circumstellar disk have a lower rotational speed than those without. In the former case, the magnetic coupling of the star to the circumstellar disk probably plays a role. This coupling presumably dissipates the angular momentum transmitted from the star to the disk into magnetically-driven outflows. With the help of the WFI at the MPG/ESO 2.2 m telescope, extensive observations were carried out of young stars in the Orion Nebula cluster (age approximately 1 Myr). In the period from 25.12.1998 to 25.2.1999, 1 – 2 images were obtained at 816 nm (exposure time 3 mins.) over some 50 nights. With each image, approximately 1000 potential cluster members were imaged. An initial examination of the data revealed that the rotational periods of some 400 cluster members could be determined via the photometric modulation of their luminosity. These luminosity variations result from correspondingly large stellar spots. If we can determine the rotational periods of so many stars in this way, we will be able to determine the rotation periods for three times the previously known sample of cluster members. A detailed data analysis will start in January 2000. In the long-term, the plan is to extend this investigation to include other, particularly older, clusters (e.g. NGC 2264) in order to study the development of angular momentum with time.

5.1.5 Jets from Young Stars

A detailed investigation of the jet of the T Tauri star, DG Tau, has been started using the STIS spectrograph of the HST. This is mainly in order to clarify the nature of the

various velocity components of the forbidden lines of T Tauri stars. In the case of T Tauri stars, a slow (approximately 5 to 20 km s^{-1}) and a fast (approximately 100 to 200 km^{-1}) velocity component are frequently observed. The fast velocity component can almost certainly be assigned to the fast jet gas. However, the nature of the slow velocity component remains unexplained. There are suggestions that it is a disk wind or a boundary layer phenomenon of the jet in the direct vicinity of the star. Also for DG Tau, two velocity components are observed, for which the velocity separation is relatively high; this is why this object is particularly suitable for investigation with STIS, because its spectroscopic resolution is only moderate. For the detailed investigation of the jet, seven slits were positioned parallel to the jet axis at a separation of $0''.07$. The data are currently being analyzed and will enable us to obtain images of the outflow in all lines investigated ([OI] $\lambda\lambda 6300, 6363$, $\text{H}\alpha$, [NII] $\lambda 6584$, [SII] $\lambda\lambda 6716, 6731$) and, in particular, at various velocity ranges. (Mundt; Bacciotti, Ray, DIAS, Dublin; Camenzind, LSW Heidelberg; Eislöffel, Solf, Thüringer Landessternwarte)

5.1.6 Herbig-Ae/Be-stars

Luminosity profiles and spectra of seven known objects in the region $5 - 200 \mu\text{m}$ were obtained with ISOPHOT. At $60 \mu\text{m}$, the central compact source is dominant. The spectrum for $\lambda < 100 \mu\text{m}$ can be described via an exponential law that best fits a circumstellar disk. For $\lambda < 100 \mu\text{m}$, the radiation of cold dust condensates in the vicinity of the source is probably dominant, and these are presumably related to the star formation process. The higher resolution of the ISOPHOT measurements compared with ISO often shows a clear separation of central object and asymmetrically arranged dust condensates. This work was carried out in collaboration with colleagues at the University of Jena. (Ábrahám, Leinert, Lemke)

5.1.7 Investigation of Luminous Star Formation Regions

S. Ligori and T. M. Herbst, working with M. Robberto, Turin, continued their investigations of W 51, one of the most luminous star formation regions in the galaxy which, due to its distance (7.5 kpc) and high interstellar extinction, is invisible at optical wavelengths. In the near infrared, images of W51 show a dense cluster of young stars as well as a complex nebula structure. Earlier photometric investigations in the near infrared (JHK) show that a large number of these objects display colors that are not exclusively due to extinction phenomena within the molecular cloud, but which are rather the result of dust emission from circumstellar disks or shells. The group observed W 51 at UKIRT with the MAX mid-infrared camera at 10 and $20 \mu\text{m}$; these images represent considerable improvement over previous measurements in the medium infrared region. At a scale of $0''.27$ per pixel and a diffraction-limited resolution, they are most comparable with NIR and radio telescope data. This allows us to draw detailed conclusions about the condition of the region, thus giving us a better understanding of the star formation processes in this kind of complex environment. In these images, the main infrared source of the region, IRS2, reveals a

complex structure with six distinguishable components. Most of the sources are linked with the radiation of ionized gas with, however, the important exception of the IRS2-3 component, which has the strongest flow at $10\mu\text{m}$ but which is located in a region without significant radio radiation.

Mon R2 is one of the closest regions of extremely active star formation (830 pc); initial investigations in the 1970s discovered a cluster of seven bright infrared sources. Subsequent studies showed a cluster of young stellar objects embedded in the mother molecular cloud. S. Ligorì and T.M. Herbst, working with M. Robberto, Turin, began an investigation of Mon R2 using data obtained with MAX and UFTI at UKIRT and covered a broad wavelength region from the near to the medium infrared. Their objective is a better determination of the characteristic features of the stellar objects present in this region in order to be able to describe the properties of the star formation process occurring there. The images obtained with UFTI were published in a preliminary version on the UKIRT Web site. This work is still in progress.

5.1.8 Age of Vega-like Stars

Vega-like stars reveal large infrared excesses caused by circumstellar dust disks that are generally thought to be the remains of T Tauri disks or the result of planet formation. Until the discovery of the first extrasolar planets by Mayor and Queloz (1995), they were the most convincing signs for the existence of planetary systems other than our own. Great progress has been made recently in the study of these systems in order to further our understanding of the structure of their disks, the spectral distribution and their development. However, there is still no detailed information about the age of these systems. D. Barrado y Navascués, in collaboration with J. R. Stauffer, J.-P. Caillault and Song (Georgia) have now revealed what they believe to be an exact age for a further prototype system: Beta Pic. They have determined that this star has two companions, close dM stars with orbital movements, that agree with those of Beta Pic to within 1 km/s (with small error bars). As a result of fitting a color luminosity diagram derived from exact photometry and Hipparcos parallaxes to evolutionary tracks, these two possible proper-motion companions of Beta Pic are thought to be very young. Comparison with theoretical evolutionary tracks reveals an age of ~ 20 million years. The chromospheric and coronal activity of these two stars also confirms their young age. The group maintains that the probability of two of the three youngest close M dwarfs having by chance the same orbital velocity as Beta Pic is very low and therefore assumes that Beta Pic and the two M dwarfs (GL799 and GL803) originated together. The estimated age of Beta Pic is then 20 ± 10 million years. This young age of Beta Pic supports the still controversial conclusion that, for Vega-like stars, the infrared excess depends on age.

5.1.9 Physics and Chemistry of Molecular Clouds

The very high frequencies of interstellar CH^+ represent an important, unsolved problem in the chemistry of cold, diffuse molecular clouds. New theoretical models describe the formation of interstellar CH^+ in gas cells that were

heated to several hundred degrees by MHD shock waves or by the dissipation of interstellar turbulence. Similarly, other molecules, such as C_2 and CH , should also be formed in the hot regions. These predictions are not confirmed by observations. From the evaluation of interstellar absorption lines from CH and C_2 in lines of sight that are characterized by very high CH^+ abundances, it was possible to show that the formation of C_2 and CH takes place at temperatures below 100 degrees, in agreement with previous models of the formation of CH^+ in cold matter. (R. Gredel)

5.1.10 $170\mu\text{m}$ Random Sampling of Galactic Sources

The investigation of the coldest knots in the ISOPHOT random sampling in the star formation regions close to the sun concentrated on Chameleon. In this test region, the comparison of the FIR measurements with deep extinction maps revealed that, with the random sampling, all cold molecular cloud cores traversed can be detected and characterized. The coldest dust (~ 13 K) was associated with $T_{\text{gas}} = (8 \pm 1.5)$ K. (Hotzel, Krause, Lemke, Stickel, Tóth)

5.1.11 Determination of Stellar Parameters from Low-resolution Spectra with the Help of Neural Networks

Extensive, deep sampling missions will produce very large volumes of data about the stellar composition of our galaxy. These missions will therefore require efficient and robust automatic systems for cataloguing the large number of recorded stars. DIVA and GAIA are typical of such missions and both are planned astrometry missions that will also observe their target objects at many different wavelengths. As a contribution to the optimization of the photometric or spectrometric systems of such missions, C.A.L. Bailer-Jones has investigated exactly how the three basic stellar parameters T_{eff} , $\log g$ and $[\text{M}/\text{H}]$ can be determined from the stellar spectra and/or multi-band filter systems as a function of the spectral resolution and of the signal/noise ratio (SNR).

The simulations were carried out with the help of synthetic spectra and neural network classifiers. A network of more than 3500 spectra was generated over a large parameter area and the resolution was then reduced step by step to 25, 50, 100, 200 and 400 Å FWHM and the SNR to 5, 10, 20, 50 and 1000 per resolution element. Filter flows for three filter systems optimized for stellar classifications were also simulated. A neural network was then focused on one part of the data in order to ascertain the relationship between the input flow measurements and the resulting physical parameters obtained. The performance of these networks was then tested on a separate set of synthetic data. This work determined for the first time that a fully automatic neural network can accurately define the three basic physical parameters from spectroscopic or photometric stellar data. A series of other interesting conclusions can also be drawn from these results. For example, the fact that even at very low SNR, “highly resolved” (50 Å FWHM) spectra can nevertheless produce good results. The current results are probably limited by the lack of precision of the data. Future work will thus concentrate on the use of improved models; in addition, the extent to which neural networks are in a position to determine fur-

ther parameters such as interstellar reddening will also be investigated. (Bailer-Jones)

5.1.12 Theoretical Investigations and Model Calculations on the Physics of Star Formation

W. Kley investigated the mass flow in protogalactic disks, the accretion of matter on Jupiter-like planets and the migration of a planet in the circumstellar disk as a result of the interaction with the environment.

A. Nelson investigated the hydrodynamic evolution of protostellar disks in double-star systems. He showed that the gravitational interaction of the double-star system induces strong density waves in the disks, which do not, however, lead to fragmentation and the formation of planets.

The fragmentation of gravitationally unstable protostellar nuclei and the formation of multiple star systems with protostellar disks was investigated by A. Burkert in collaboration with P. Bodenheimer (Santa Cruz, CA). Using statistical methods, Burkert and Bodenheimer investigated the origin of the angular momentum and the rotational properties of turbulent molecular nuclei. Initial numerical collapse simulations were carried out of turbulent cloud nuclei.

As part of his PhD thesis and in collaboration with A. Burkert, O. Kessel is investigating the induced star formation in gas regions that are ionized and compressed via a near OB association. A recently developed procedure for treating the ionising radiation for smoothed particle hydrodynamics simulations was used for this.

R. Klessen and A. Burkert studied the dynamics and fragmentation into stars of turbulent gas clouds. They found that gravitationally unstable, turbulent gas clouds condense into stellar clusters with mass distributions that agree well with the observed mass distribution of young stellar clusters. The dependency of star formation on the initial conditions chosen was investigated in greater detail and compared with the observations.

The formation of clumpy, cold molecular clouds due to cooling instabilities from an initially warm, diffuse gaseous phase was investigated by A. Burkert in collaboration with D. Lin (Santa Cruz, CA). They showed how turbulent, clumpy gas clouds can form in the cooling phase, and what influence galactic magnetic fields can have on this process.

The formation of young stellar clusters in dense molecular clouds and their development during the destruction of the gas clouds by stellar winds and ionising radiation of young stars was investigated by Michael Geyer in collaboration with A. Burkert.

In collaboration with M. MacLow (New York, USA) and Ralf Klessen (Leiden), F. Heitsch investigated the dynamics of magnetized, turbulent gas clouds, taking the effect of self-gravitation into account. They found that turbulence in gas clouds cannot be driven by internal sources and thus has to be a consequence of their formation.

In collaboration with A. Burkert, Michael Geyer is using numerical simulations to investigate (PhD thesis) the stability of young globular clusters in molecular clouds. Soon after the formation of a globular cluster in a molecular cloud, the remaining gas is driven out of the system (gas expulsion phase). Whether the globular cluster survives as a bound

system is determined essentially by the star formation efficiency and the time scale of the gas expulsion phase. Even in the case of low star formation efficiency, they find that bound systems can exist.

5.1.13 Stellar Dynamics of the Milky Way Disk

Walter Dehnen continued research he started in Oxford into the influence of the galactic bars on the velocity distribution of stars close to the sun (see Dehnen 1998, AJ 115, 2384). In addition to the main body of stars in almost circular orbits, he finds a second mode with radial outward velocities of approximately 50 km s^{-1} and approximately 40 km s^{-1} slower in azimuthal movement than a local orbit. Such a bimodality can be easily explained by the influence of the galactic bars: stars in orbits whose natural frequencies are almost in resonance with the rotation rate of the bars sometimes deviate considerably from the generally almost circular movement around the center of the Milky Way. As extensive simulations determined, the structure of the local velocity dispersion can even be reproduced down to the finer details, provided that the sun is located approximately 1 kpc outside of the outer Lindblad resonance of the galactic bars and approximately $\phi = 10^\circ - 70^\circ$ behind its main axis.

The parameters of the galactic bars, especially the rotation rates, are not determined sufficiently accurately by observations and simulations of the inner Milky Way alone. The influence of the local stellar kinematics, however, offers a new possibility for determining these parameters. A quantitative comparison of simulated and measured velocity dispersion of the stars produces a value of 1.75 to 2 for the relation between the rotation rates of the bars and the local orbits, depending on the exact shape of the galactic rotational curve and the value of the angle ϕ (Dehnen 2000, AJ 119, 800). If one further uses the gas velocities within the solar orbit and the proper motion of Sgr A* in order to establish the rotational curve of the Milky Way, one obtains $53 \pm 3 \text{ km s}^{-1} \text{ kpc}^{-1}$ for the rotation rate of the bars and a co-rotation radius of $R_{CR} \sim 5 \text{ kpc}$ (Dehnen 1999, ApJ 524, L35). This produces the value 53 ± 0.2 for the ratio of R_{CR} to the half length of the bars, which is in agreement with the estimates for some external galaxies. (Walter Dehnen)

5.1.14 Optimum Softening in N -body Calculations

In numerical simulations of collision-free stellar dynamics by means of N -body calculations, the gravitation is damped at small scales in order to avoid the otherwise very strong forces at small distances. Alternatively, this softening can also be viewed as a method for estimating the true forces of the stellar system as modelled from N positions, which are randomly selected from this stellar system. Without any softening, forces from random close encounters, (i.e. the noise created by the much smaller number N from simulated as modelled stars), are considerably in error. On the other hand, too much softening leads to a systematic error. Optimum softening avoids both extremes and minimizes the deviation of the forces from those of the stellar system to be modelled. The dependence of this deviation on (i) the softening length ϵ and (ii) the softening kernel, the function by which the Newtonian Greens function is replaced, was investigated

thoroughly both theoretically and by means of numerical experiments. The work was not yet complete by the end of the year but some essential results are already clear. (1) Compact kernels, i.e. those that yield exact Newtonian forces at finite values of r , produced distinctly smaller force errors than the widespread ‘‘Plummer softening’’, in which the Newtonian $1/r$ is replaced by $1/(r^2 + e^2)^{1/2}$. (2) In particular, special kernels can be derived that further reduce the error by compensating for the attenuation of the force at $r < \varepsilon$ by somewhat larger forces at $r \sim \varepsilon$. (Walter Dehnen)

5.1.15 Comets, Asteroids and Zodiacal Light

Measurement of striae structures in the dust tail of the Hale-Bopp comet (C/1995 O1) on a set of digitized Schmidt photographs from Calar Alto and from observers at other locations, were completed. These measurements were performed from March and April 1997, at the time of best visibility of the striae before and after the perihelion passage of the comet. The data and the description of its reduction and analysis have been prepared for publication. Z. Sekanina is modelling the formation of the striae and their movement through the dust tail. In this context, the question of the formation of the nucleus fragments, from which the striae later form in the dust tail, and their migration from the nucleus of the comet, requires the extension of the fragmentation model of Sekanina and Farell of 1980. (Birkle; Bönhardt, ESO; Ryan, Galway University, Ireland; Sekanina, JPL, USA)

A taxonomic investigation of Trans-Neptunian objects (TNO) has been started in collaboration with H. Bönhardt (ESO), B. Marsden (Cambridge, Ma), K. Meech (Hawaii), G. Tozzi (Florence), J. Watanabe (Tokyo) et al.. Using photometry and spectroscopy in the optical and NIR, a larger number of asteroids from the Kuiper Belt will be classified with regard to size, surface quality and rotation. Several observing nights at the VLT and at the 3.5 m telescope on Calar Alto have been approved for the first half of the year 2000. (Birkle)

ISOPHOT polarization measurements of the asteroids (6) Hebe and (9) Metis at $25 \mu\text{m}$ yielded polarization values of $< 0.5\%$, although for these elongated objects, a few percent net polarization had been predicted. This permits the extension of the thermo-physical model of Lagerros. It now also includes the polarized thermal emission including the irregular form, the rotational state, the thermal inertia, the wavelength-dependent emissivity and the small-scale surface roughness. For Metis, a combination of high surface roughness (proportion of craters) and low refractive index is revealed. (Klaas; Müller, ESA, Villafranca)

6 EXTRAGALACTIC ASTRONOMY: PROGRAMS AND RESULTS

6.1 Calar Alto Deep Imaging Survey (CADIS)

Participating scientists: The following scientists and students at the MPIA participated in CADIS during the year of this report: Fried, Hippelein, von Kuhlmann, Leinert, Maier, Meisenheimer (Project Leader), Phleps, Rix, Röser, Thier-

ing, Chr. Wolf. Also: Aguirre, Alises (Calar Alto); Huang (CfA, Boston) and Thommes (Royal Observatory, Edinburgh).

6.1.1 Instrumentation

All three sampling instruments, CAFOS (at the 2.2 m telescope), MOSCA and OMEGA Prime (at the 3.5 m telescope) are working satisfactorily. At the beginning of the year, the Loral Chip was replaced at MOSCA with a SITE 4K x 2K CCD. For $\lambda > 700\text{nm}$, this had considerable advantages; in particular, a high quantum yield and hardly any fringing. As mentioned in the 1998 Annual Report, the J filter is now used as NIR band. The aimed at $10\text{-}\sigma$ limit $J = 21.8$ mag is actually achieved with OMEGA Prime after a 10 ks integration time.

6.1.2 Observations

We were able to observe during 51.5 nights (48%) of 108 nights total observation time at the 2.2m and 3.5m telescope (CAFOS: 51, MOSCA: 33, OMEGA: 24). 35% of the time was lost due to cloud, 10% due to poor observation/seeing and 6% due to technical problems. On the basis of the long-term weather statistics, 1999 was the first year to slightly surpass our expectations. Fortunately, an outstanding first half year made up for the failure of the previous year. As a pilot project for the preparation of service observations, two telescope operators were closely involved in the CADIS observations. After an initial starting period, standard survey observations can now be carried out independently by Calar Alto staff.

As in the previous year, great importance was placed on completing the Fabry-Perot observations, so that we were able to complete fully the observations in the 9-h field in the year of this report (all filters plus three Fabry-Perot intervals, FPI-A,B,C). We have also obtained almost complete data in three further fields (01h: FPI-B; 16h: FPI-A,B,C; 23h: FPI-A,C). The multi-color survey is almost complete in two fields (Lockman Hole, North Pole of the elliptic), thus there are now only large data gaps in the 13h field. (All CADIS scientists)

6.1.3 Data Analysis Methods

The proper correction of the flatfield is of vital importance for a reliable discovery of emission lines at the verification limit. Once it was recognized that the Fabry-Perot etalon in CAFOS introduces additional, reflected light, this part had to be separated off for the flatfield correction. A mask with a regular perforation was used for this purpose. The ratio of the signal through an aperture with and without etalon produces the pure transmission property of the etalon. A standard procedure was developed for deriving the actual flatfield for etalon images from the perforated mask images in the pre-filter, with and without etalon, as well as the associated flatfield. (Röser, Meisenheimer)

Spectroscopic follow-up observations of the CADIS objects (e.g. at the VLT, see below) require an astrometric position determination. The astrometry program used thus far in CADIS was created using VMS. Now that these computers are no longer in use, a set of commands was developed

for the astrometry in CADIS using the MIDAS context, AS-TROMET. These enable the determination of the position of secondary, astrometric standard stars on the basis of the PPM catalogue and the Digital Sky Survey (DSS). The unknown proper motions of the secondary standard stars only enable the attainment of the desired accuracies of some $0''.1$ if DSS II is used. Careful analyses in the run-up to the follow-up observations have shown that this accuracy really can be achieved with the CADIS positions (corrected for distortion). (Röser)

By improving the templates for stars and quasars, as well as a better calibration of the tertiary standard stars in each CADIS field, it was possible to further increase the reliability of the multi-color classification: both self-tests (Monte-Carlo simulations) and the comparison with 160 spectroscopic objects subsequently observed show that, for $R \leq 23$, some 98% of all objects are correctly categorized according to star, quasar or galaxy. In addition, 95% of all galaxies with $I_{815} \leq 23$ in the $0.2 < z \leq 1.05$ region are allocated a redshift whose typical internal error of $\sigma_z \approx 0.025$ is in good agreement with deviation from the spectroscopically determined redshifts. Only 5% of all galaxies show greater deviations and unsatisfactory agreement with the template colors. These are obviously galaxies whose spectra are poorly represented in our library. (Chr. Wolf, Meisenheimer, Röser)

6.1.4 Spectroscopic Follow-up Observations and Ly α Primeval Galaxies

In an attempt to probe the limits of the spectroscopic observations with MOSCA, it was revealed that at $\lambda = 820$ nm, even after 10 hours integration time, emission line objects at the survey limit ($F_{\text{line}} = 4 \times 10^{-20} \text{ W m}^{-2}$) can, at best, be verified on the 3σ level. The marginal evidence of an Ly α candidate in the 16h field thus has to be verified by means of deeper spectroscopy. The unsatisfactory verification limit is, above all, due to the fact that the only grism that enables the observation of the area around $\lambda = 820$ nm only exhibits less than 60% of its maximum transmission there. Thus, a new grism was ordered (delivery: April 2000). Together with the SITE 4K \times 2K CCD, it should be possible to increase the overall efficiency of MOSCA at 820 nm by at least a factor of 2 and so enable the verification of the brightest Lyman α candidate from Calar Alto.

In November, we were able, for the first time, to use the magnificent possibilities opened up by the VLT to the European astronomy in one of the equatorial CADIS fields (01h field). In two half nights with excellent conditions, we were able to observe two multi-object settings (MOS, each of 19 slits) with FORS I. After 3.5 hours integration time, we were able to obtain good confirmation for 5 of the 13 emission-line candidates observed at the CADIS verification limit ($F_{\text{line}} = 4 \dots 6 \times 10^{-20} \text{ W m}^{-2}$). However, the six promising Lyman α candidates that were found on the two MOS are amongst the non-verified objects. For the first time, the high number of observed candidates enables a statistical comparison of the Fabry-Perot (FP) data with spectroscopic observations, yielding the following results:

1. The FP observations with the standard set-up (CAFOS + SITE 24 μm) are reliable. Of five objects close to the

verification limit ($4 \times 10^{-20} < F_{\text{line}} \leq 7 \times 10^{-20} \text{ W m}^{-2}$), only two cannot be verified. One of these is called up by combining a reflection below the verification limit with a $3\text{-}\sigma$ noise maximum. The other is a variable object that was only bright in the epoch in which one of the FP wavelengths was recorded.

2. The strong fringing of the Loral CCD in MOSCA leads to additional noise that, until now, has not been quantifiable. The effective verification limit is thus 1.35 times as high as assumed.

3. Each ‘‘false’’ FP signal – be it created by underestimated noise or by variability – inevitably occurs in our sample of Lyman α candidates, since it satisfies exactly the same criteria (FPI signal in at least one wavelength, no flow at $\lambda < 600$ nm). This unavoidable contamination of the Lyman α samples can only be reduced further by ensuring consistency of the FP signal with the flow measured in the pre-filter.

Although this first VLT campaign did not lead to the verification of a Lyman α galaxy, its result is nevertheless encouraging. We have confirmation that CADIS also detects reliable emission line galaxies close to the verification limit, and that some three hours’ integration with FORS are sufficient to enable details of such emission lines to be detected. However, these observations also show that, up to the limit of $5 \times 10^{-20} \text{ W m}^{-2}$, as are achieved in the 01h field, Lyman α galaxies are very rare ($< 2/\text{field}$). For this reason, at the end of 1999, we observed a second independent set of FP data in the 01h field, that pushes the verification limit to $\leq 3.5 \times 10^{-20} \text{ W m}^{-2}$ and excludes contamination by variable objects. (Chr. Wolf, Meisenheimer, Röser, Thommes)

6.1.5 Galaxies at Medium Redshift

With the improved multi-color method, we now have an outstanding basis for statistical analyses of the galaxy population at medium redshift. In the year of this report, we examined the problem of the luminosity function and its development. In the three fields with an almost complete set of data (01h, 09h and 16h fields), we find 2779 galaxies up to a limit size of $I_{815} = 23$, for which a usable redshift and spectral energy distribution (SED) can be given. Note that galaxies can be differentiated from stars and quasars by means of their SED *alone*.

We use two complementary methods to determine the luminosity function: the $1/V_{\text{rmax}}$ method delivers a direct image of the luminosity function, whereas the Maximum Likelihood or Sandage-Tammann-Yahil method adapts an optimum Schechter function to all galaxies found in the survey.

With both methods, we take the influence of (SED dependent) selection effects into consideration by determining an instrumental transfer function that states which proportion of the actual galaxies present from a bin at (m, z, SED) can be correctly found again in the same bin. A further advantage of the CADIS analysis is that the flow in the (redshifted) B-band can be determined directly from the data and it is thus no longer necessary to model the k correction. Thus, the luminosity functions for galaxies at $0.2 < z \leq 1.05$ are not only clearly statistically (just the three fields analyzed here

contain almost five times the number of galaxies than found in the whole Canadian-French Redshift survey, CFRS) superior to those of other surveys, but also systematically. The CADIS sample is large enough to investigate the evolution of the galaxies in the $z = 0.2$ to $z = 1$ region independently of galaxy type. 1.

1. The bright galaxies ($L \geq 1/10L^*$, L^* indicates the characteristic luminosity) of the early Hubble type (SED = Sb or earlier) display *no* evolution of the luminosity function between $z = 1$ and $z = 0.2$. 2.

2. The galaxies of the late Hubble type (later than Sb) display a moderate development in L^* (at $z = 1$ some 50% brighter than today) and a clearly steeper increase of the luminosity function at $z = 1$, that is due to a population of dwarf galaxies with high star-formation rates.

Similar results were produced by the CFRS, but with a much smaller sample and hence less significance. (Fried, von Kuhlmann, Meisenheimer, Rix, Chr. Wolf)

6.1.6 Extreme Red Objects (EROs)

As CADIS covers a relatively large area with deep K' photometry (up to $K' \geq 19.5$ mag), our survey is ideal for a systematic investigation of the population of extreme red objects. Initial follow-up investigations in the sub-mm regime (SCUBA) and in the NIR (highly resolved images at the Keck 10m telescope) allow us to suspect, however, that, with the EROs, we are not dealing with a uniform class of galaxies at $z > 1$, but rather with a mixture of extreme representatives of various object classes. In this way, relatively close, edge-on spirals and starburst galaxies at $z > 1$ are found as EROs, as well as low-mass stars in our Milky Way.

6.1.7 Stars of the Milky Way

Although CADIS is predominantly an extragalactic project, it depends on identifying all stars in order to prevent contamination of galaxies and quasars. The some 300 stars found by us in two CADIS fields are eminently suitable for investigating the structure of the Milky Way. As these are exclusively very weak, main-sequence stars ($R \geq 16$ mag), their distances can be determined using photometric parallaxes. Up to a limit size of $R = 23$ mag, at which the star/galaxy classification operates with a $> 98\%$ accuracy, we find stars up to ≈ 25 kpc above the galactic plane. The incompleteness that increases with distance can be corrected on the basis of a color distance diagram. Thus, it is possible to determine directly the density of stars along the line of sight.

The structure of the galactic halo follows a de-Vaucouleurs law. The distribution of the stars in the galactic disk clearly indicates an excess that can be explained by means of a so-called "thick disk" that, at $h_2 \approx 1200$ kpc, displays a substantially larger scale height than the thin disk ($h_1 \approx 280$ kpc).

In view of the information about the distribution function, it is possible to determine the luminosity function up to a brightness of $M_V = 13$ mag with very small errors. We cannot confirm the decrease of the luminosity function on the other side of $M_V = 10$ mag proposed in all previous photometric surveys, but we find very good agreement with the

local luminosity function derived from HIPPARCOS parallaxes. The luminosity function of the disk stars reveals a continuous increase, and this applies even to the weakest of the absolute luminosities observed. (Phleps, Meisenheimer, Chr. Wolf; Fuchs, Jahreiß, ARI Heidelberg)

6.2 Extragalactic Astronomy with ISO

6.2.1 Infrared Observations of Near Galaxies

The spectral energy distribution in the 10-200 μm range in the nucleus and disk was measured with ISOPHOT for the NGC 7582 galaxy, which is the prototype of a "narrow-line X-ray galaxy". The nuclear luminosity (within a radius of 2 kpc) is dominated by a 32 K warm dust component. In addition, there is an AGN-heated component, recognisable by a dust temperature of 122 K, whose luminosity is one third of the luminosity of the 32 K component and which is also responsible for the X-ray radiation. For the first time for this galaxy, it was possible to determine the temperature and mass parameters of the dust in the disk. In addition to a 30 K component, that indicates an expansion of the circumnuclear starburst up to a radius of 7 kpc, the 200 μm measurements found a cold dust component with 17 K, which contains 85% of the dust mass ($10^8 M_\odot$). The dust/gas ratio for this galaxy is thus 1/100. The mass of the dust, which is associated with the AGN activity, is only $10^3 M_\odot$. (Radovich, Klaas, Lemke)

The spectral energy distributions (SEDs) of the 37 brightest ultraluminous IR galaxies (ULIRGs, $L_{\text{fir}} > 10^{12} L_\odot$) were measured with ISOPHOT between 10 and 200 μm . Follow-up observations with JCMT/SCUBA at 450 and 850 μm under best atmospheric conditions delivered flow values for 6 objects. Two objects were measured at 1300 μm with SEST. In this way, it was possible to increase the number of ULIRGs with measured SEDs between 10 and 1000 μm from 7 to 15. With the extension of the SEDs into the NIR and the optical, it is now possible to derive the luminosity components as well as the dust temperatures and masses for this object class and to search for systematic differences in the SEDs. This allows us to judge the relative contributions of various hot sources, such as AGN, starburst or interstellar radiation field. (Klaas, Haas, Hippelein)

The far-infrared chart generated with ISOPHOT at 170 μm shows a wealth of bright knots arranged in a circular pattern. A detailed investigation and the comparison with infrared charts at 60 and 100 μm , as well as HI, HII and CO charts, show that most of these knots really are correlated with known star formation regions or with molecular cloud complexes. The star formation rate in M 31 is about a factor of 5 to 10 times lower than in the Milky Way. (Schmidtbreick, Haas, Lemke)

Taking two galaxies with distinctive bar components (NGC 3992 and NGC 7479) as an example, consistent mass models were generated from the NIR surface luminosity distribution. In doing so, particular emphasis was placed on the modelling of asymmetric bars. The model predictions for the rotation curves were found to be in good agreement with the observed curves. Furthermore, it was revealed that changes in the bar mass influence the model kinematics at given bar asymmetry considerably more than moderate changes in the

bar asymmetry itself. (K. Wilke, in collaboration with M. Matthias, Munich, and C. Möllenhoff, Heidelberg)

6.2.2 Quasars

Together with the Astronomical Institute at the University of Bochum, 17 quasars from the Palomar-Green catalogue were investigated from the near to the far infrared during the guaranteed time with ISOPHOT. Compared to IRAS, the verification rate could be increased from 6/17 to 14/17. Dust masses of $10^6 \dots 10^8 M_{\odot}$ were derived from the spectral energy distributions. Based on the various forms of infrared SEDs, we suggest the following mechanisms for dust heating: the environment of a black hole in the galaxy nucleus makes for the 500–1000 K hot dust components, whereas star formation regions heat the main part of the dust to 30–120 K. The correlation of the luminosity of both dust components was explained as follows: the greater the disturbance of the angular momentum of the interstellar matter, the greater are the rates for both the star formation in the outer quasar regions and the feeding of the black hole in the center. This is in agreement with the hypothesis that quasars form due to galaxy interaction. (Haas, Müller, Meisenheimer, Klaas, Lemke)

6.2.3 Infrared Background Radiation

The evaluation of several deep samples with ISOPHOT led to initial source counts at 90, 150 and 180 μm . Whereas the logN-logS diagrams obtained from IRAS at 90 μm yield a smooth transition to weaker galaxies, the source densities at the longest wavelengths are clearly above the predictions for galaxy models with evolution. With increasing redshift, such models have a greater proportion of luminous galaxies (ULIRGs, starbursts,) Galaxy models without evolution can certainly be excluded. This work is carried out together with colleagues from the universities of Helsinki and Copenhagen, as well as with the Institut d'Astrophysique Spatiale in Paris. In order to finally determine the integrated FIR sky luminosity, work continued on the foreground components zodiacal light, interstellar and intergalactic dust emission. (Lemke, Abraham, Haas, Klaas, Leinert, Stickel)

6.2.4 ELAIS Galaxy Sampling

In the year of this report, the preliminary ELAIS galaxy catalogue, based on ISO observations, was completed and published. Programs for the analysis of ELAIS/PHT data were developed further and co-ordinated with the latest version of the PHT Interactive Analysis. The preliminary ELAIS catalogue of very reliable sources from ISOCAM and ISOPHOT observations was made available in August 1999 on the public ELAIS Web site. An intensive program of follow-up observations of the ELAIS sampling area is currently running on telescopes on the Canaries, Hawaii, Australia, Chile and New Mexico. To this end, the ISO sources first had to be identified with optical counterparts in order to have sufficiently good positions. The most important follow-up programs include: 1). CCD samples at visible wavelengths, 2.) CCD samples in the near infrared, 3.) radio samples (VLA and AT), 4.) optical spectroscopy, 5.) infrared spectroscopy. In addition, an application was submitted for

X-ray observations with XMM Newton, so that many ELAIS galaxies will, in the end, have luminosity values for the following wavelength regions: 2-10 keV, U, B, V, R, H, K, 6.7, 15, 90, 170, 450, 850 μm , 6 cm, 21 cm.

The ELAIS work will continue to be supported by the European Research Network TMR, whose support until the end of the application period (September 2000) was confirmed after a half-time review in February. (Héraudeau, Lemke, Klaas)

6.2.5 Random Sampling at 170 μm

After improving the ISOPHOT calibration, a second complete analysis of more than 12000 serendipity slews was carried out with regard to compact sources. A first large serendipity source catalogue was generated from the results obtained. It contains 115 compact sources that were traversed centrally with the C200 camera on a low cirrus background and that are optically associated with mainly spiral galaxies.

The analysis of the far infrared properties of this group revealed that cold dust with temperatures between 15 and 20 K is to be found in virtually all galaxies observed. The stellar masses derived are in the region of 10^7 to 10^8 solar masses, and are thus some 2 to 10 times larger than the values derived from IRAS data. Together with the gaseous masses derived from radio observations, the new dust masses produce a distribution of the gas-to-dust mass ratio that is scattered in the range from 10 to 1000. Its most frequent value is in agreement with the value found for the Milky Way (~ 160).

The first galaxy catalogue, together with statistical analyses, was prepared for publication. (Stickel, Lemke, Klaas, Hotzel, Tóth)

6.3 Other Observing Programs

6.3.1 The Jet from 3C 273

Evaluation and analysis of the ROSAT HRI data: the X-ray data of the jet from 3C 273, which have already been briefly introduced in a previous report, were finally evaluated and analyzed. The main result is the evidence of X-ray radiation along the whole of the visible jet. Unlike the morphology in the radio and optical regions, where the outwards radiation rises steeply or remains more or less constant, the maximum X-ray emission at the inner end of the visible jet is at the knots A and B. The outwards X-ray emission is very weak. As was already suspected, the emission from knot A can be explained by means of synchrotron radiation. The strength of the X-ray emission of the hotspot is consistent with synchrotron self-Compton radiation. With the other knot, it is, however, still unclear as to how the X-ray radiation forms, since even thermal Bremsstrahlung is hardly a viable explanation in view of the high electron densities required. (Röser, Meisenheimer; Conway, Jodrell Bank; Perley, Socorro)

Evaluation and analysis of the HST-WFPC2 data: the HST images of the jet from 3C 273 at 300 nm and 600 nm wavelengths were smoothed at a resolution of $0''.2$ and combined to form a chart of the optical spectral index. The spec-

tral index changes slowly and continuously along the jet, which must also apply to the physical conditions. The chart shows the spectrum gradually becoming steeper within individual knots and a flattening in the intermediate knot region. Such behavior would not be expected if the knots were strong shocks such as the hotspot, rather it indicates that a non-localized acceleration process is at work. (Jester, Röser)

Evaluation of the VLA data: Our extensive VLA data from the jet from 3C 273 have now been fully recorded. The calibration of the data sets and the generation of the combined databases is complete. Initial charts have been created. There are plans to complete this part of the project in the spring of 2000 so that it can be combined with the HST data in order to discuss the synchrotron continuum. (Perley, Röser)

6.3.2 Search for High Redshift Galaxy Clusters

In recent annual reports, a project was introduced in order to create a sample of optically selected galaxy clusters with redshifts $z > 0.5$. This sample should help to clarify the question as to the cause of the observed development of galaxies in clusters during the second half of the age of the universe. The data for our sampling is made available by M.R.S. Hawkins (Edinburgh). It consists of the digital superposition of 64 111a-J and IIIa-F or 30 IV-N UK Schmidt plates of a southern field. During the period covered by this report, the comparability of the object sample based on the photographic data with other data taken from the literature was also verified in view of the galaxy-galaxy correlation functions. In this way, it was possible to investigate both the photometric calibration and the object detection in the field observed. These two comparisons confirmed the unrestricted applicability of the object list generated. In addition, by investigating two simulated sets of data, made available in their original form by J. Kepner (Princeton), the quality of the cluster search algorithm developed was obtained. In doing so, it was initially necessary to adjust the simulated data to our survey data in terms of their photometric properties and the usable regions. The results obtained here show that the algorithm developed, which investigates two-dimensional distributions of galaxy density via a statistical procedure, has a detection rate comparable to that of a matched-filter algorithm which also accesses information obtained from the redshift of objects. Based on these investigations, work has started on the generation of the final list of galaxy cluster candidates. (Baumann, Röser; Hawkins, MacGillivray, Edinburgh)

6.3.3 Galaxies, Black Holes, Gravitational Lenses

Rix and Rudnick (Steward Observatory) have investigated whether spiral galaxies with clear asymmetries (“lopsided galaxies”), which have probably formed due to interactions with satellite galaxies, contain more young stars than symmetrical galaxies of the same luminosity. The spatially integrated spectra of the asymmetrical galaxies really do exhibit very many more A stars, corresponding to an additional star formation rate of $5 \times 10^8 M_{\odot}$ in the last half gigayear. This result shows that even non-cataclysmic gravitational interactions, which only lead to disk disturbance, and not destruc-

tion, can considerably modulate the star formation rate in spirals, and suggests the conclusion that a good part of the stars were formed in such boost episodes.

Rix and a group of colleagues (Shields, Ohio; Ho, Carnegie Observatories; Filippenko, Berkeley; MacIntosh and Rudnick, Steward Observatory) analyzed HST long-slit spectra of 24 near galaxy nuclei in order to investigate the nuclear (< 2 pc) line emission and stellar population without the overwhelming contribution of the projected stellar light from the bulge. Two important results have been obtained so far from SUNNS (Survey of Nearby Nuclei with STIS): (1) line emissions with widths of more than 300 km/s appear to be very frequent in AGNs of low luminosity. (2) What, in ground-based data, often appears to be “nuclear” star formation often proves to be circumnuclear (> 5 pc); young stars at < 1 pc, such as those in the center of the Milky Way, appear to be relatively rare.

M. Sarzi (Padua) and H.-W. Rix determined the masses of black holes in the nuclei of five near spiral galaxies by modelling gas rotation curves obtained with the STIS spectrograph on the HST. In four objects, it was clearly revealed that the steep rotational gradient in the center cannot be explained by the stellar mass alone. Interestingly, it is shown that the scatter in the $M_{\text{BH}}/M_{\text{Bulge}}$ ratio is much greater than claimed previously (e.g. by Magorrian et al. 1998).

Together with the CASTLES team (C. Impey, C. Peng, C. Keeton, Steward Observatory; C. Kochanek, E. Falco, B. McLeod, J. Lehar, CfA), H.W. Rix continued a larger observing program of gravitational lenses with the HST. Within the scope of this program, almost all known lens systems with image separations $< 10''$ were imaged in the near infrared. The deep images of high spatial resolution have demonstrated the lens galaxies in virtually all lens systems. Thus, for the first time, it was possible to investigate the properties of the lens population:

26 out of 28 lenses are elliptical or S0 galaxies whose mass-luminosity ratio suggests “old” ($z_{\text{Formation}} > 2$) stellar populations. Furthermore, it was possible to image the host galaxies, which were greatly magnified due to the lensing effect, in a large number of the quasars. It was revealed that even bright quasars live in galaxies of relatively low luminosity. As it is plausible that the quasars lie below the Eddington limit, the lower mass limit of the central black hole can be estimated. This shows that, at $z \approx 2$, the black hole was more massive in relation to the surrounding galaxy than is the case today ($z \approx 0$). The central black holes have thus grown more quickly than the host galaxy.

Thilo Kranz and H.-W. Rix have investigated the gas kinematics in spiral galaxies in order to obtain the relative contribution of the stellar disk and the dark halo to the overall mass within the optical radius. As the stellar disks in the near infrared reveal strong spiral arms, which represent a strong contrast to the stellar mass, one would expect the velocity field of the gas to be coherently perturbed by the spiral arms if these make the greatest contribution to mass. On the other hand, one would expect an almost undisturbed velocity field if the dark halo (without spiral arms) perturbs the gravitational potential. K-band images of spirals were used in order to predict the disturbed velocity field and then

compared with H α Doppler measurements. Initial results indicate that even within 5–10 kpc, the dark matter makes up the majority of the overall mass.

H.-W. Rix and Joanna Hinz (Steward Observatory) have investigated the Tully-Fisher relation between stellar luminosity and maximum rotational velocity for S0 galaxies. The rotational velocity for 14 objects in the Coma cluster had to be determined by means of complicated absorption-line spectroscopy and the following modelling was obtained. Surprisingly, the result was as follows: the central velocity dispersion (Faber-Jackson relation) correlates much better with the overall luminosity than the maximum rotational velocity. Furthermore, at the given rotational velocity, S0 galaxies in the I band are just as bright as Sc galaxies, although the stellar M/L values should differ by a factor of two. Perhaps this indicates that, in S0 galaxies, the proportion of dark matter is smaller.

6.4 Theoretical Investigations and Model Calculations

6.4.1 Structure, Dynamics and Development of Galaxies

In collaboration with K. Prendergast (Columbia, USA) and J. Silk (Oxford) and the help of numerical models, A. Slyz investigated the connection between the viscous development of galactic disks and their star formation. The gas dynamics in NGC 4254 in the stellar potential was investigated by A. Slyz in collaboration with T. Kranz and H.W. Rix.

Chemodynamic calculations on the self-regulating development of dwarf galaxies were carried out by R. Andersen and A. Burkert and the energetic interaction between the star components and the surrounding gas was investigated.

Together with A. Burkert, Masao Mori investigated the interaction of dwarf galaxies with the hot, diffuse gas components in galaxy clusters. It was shown that, during their orbit through the inner regions of galaxy clusters, dwarf galaxies can lose their diffuse, metal-rich gas as well as part of the cold gas component to the cluster. This has a strong influence on the history of their star formation and chemical evolution.

A. Burkert investigated the formation and nature of dark matter halos. Initial numerical calculations were carried out of halos from dark elementary particles that interact weakly with one another. These calculations show a long-term evolution that might explain some important problems of cosmological models of cold dark matter.

Thorsten Naab (PhD thesis) in collaboration with A. Burkert used numerical simulations to investigate the formation of elliptical galaxies by the merging of spiral galaxies. It was revealed that the formation of isotropic, rotation-supported and “disky” ellipses can be understood as being the result of the merging of galaxies with very different masses. Anisotropic, “boxy” ellipses, however, form as a result of the merging of spiral galaxies of similar mass. Initial calculations were carried out with an additional gas component.

In collaboration with A. Burkert, S. Khochfar investigated, as part of his PhD thesis, the merging history of dark

halos and the formation of disk and boxy elliptical galaxies for various cosmological models.

As part of his PhD thesis, R. Jesseit together with A. Burkert investigated the influence of galactic disks and galactic winds on the dynamics and structure of halos from dark matter.

6.4.2 A Model of NGC 2320

N. Cretton modelled the kinematics of stars and gas in NGC 2320 in accordance with the Schwarzschild superposition method. This involves calculating an extensive set of orbits in a specified potential that corresponds to the deprojected surface luminosity of the galaxy. The gravitational contribution of dark matter can also be considered. The orbits are combined and weighted in such a way that the starting model is reproduced for the density distribution and a set of kinematic boundary conditions are fulfilled. The result yields a representation of the internal structure of galaxies that is independent of any assumptions regarding the kinetics.

In the case of NGC 2320, two types of gravitational potentials have been considered: those in which the mass is distributed in the same way as the luminosity (namely without dark matter), and those gravitational potentials with a logarithmic variation. In the former case, a mass-luminosity relation $Y_V = 15.0 \pm 0.6 h_{75}$ is produced in the visible region, in the second $Y_V = 17.0 \pm 0.7 h_{75}$. Models with radially constant Y_V and logarithmic models with dark matter describe the observations just as well and reveal a similar dynamic structure. Within the whole Y_V region compatible with the observations, the kinematics of the models is radially anisotropic ($1'' < r < 40''$) in the equatorial plane. Along the true half axis, the anisotropy is less. For the model with the best fit, $\sigma_r / \sigma_{\text{total}} \approx 0.7$, $\sigma_\phi / \sigma_{\text{total}} \approx 0.5 \dots 0.6$ and $\sigma_\theta / \sigma_{\text{total}} \approx 0.5$ in the equatorial plane.

6.4.3 Dynamics of Low-luminosity Galaxies

In the autumn, N. Cretton, working with T. Naab, A. Burkert and H.-W. Rix, commenced a project for N-body modelling of the merging disk galaxies of unequal mass in order to check whether the kinematic properties of the merged products (especially the rotational energy) are comparable with those observed in low-luminosity elliptical galaxies. Seen from the side, their v/σ profiles increase too weakly compared with the observations: they reach the value 0.5-1 at $R_{\text{eff}} = 1$ mag and 1.4-2 at $R_{\text{eff}} = 3$ mag, while $v/\sigma = 2$ is already observed within $R_{\text{eff}} = 2$ mag. The Gauss-Hermit moment h_3 , which describes the velocity distribution along the line of sight, is positive in the model within $R_{\text{eff}} = 1$, whereas it drops for the low-luminosity “disky” elliptical galaxies from zero in the center to -0.1 at $R_{\text{eff}} = 0.5$ mag. Seen from the side, the model products appear flattened (ellipticity 0.6): in order to achieve a more satisfactory agreement with the average ellipticity 0.3 from the sample observed by Rix *et al.* (1999), the modelled merged products have to be inclined by $\sim 50^\circ$. Consequently, their v/σ profiles are further decreased in comparison with the edge-on-

value. This result adds weight to our conclusion that this type of merging cannot be considered as the origin of the low-luminosity elliptical and S0 galaxies.

7 CONFERENCES, COLLOQUIA, PUBLICATIONS, MISCELLANEOUS

The 13th Calar Alto Colloquium took place in Heidelberg in March with more than 20 short talks.

As Principal Investigator, Lemke had overall responsibility for the ISOPHOT experiment.

A training course for teachers from the Land of Baden-Württemberg took place in the Institute in October. (Chr. Leinert)

As senior editor, Staude, assisted by Neckel, Quetz and Neumann, organized the journal “Sterne und Weltraum”, which is now in its 38th year.

29 groups, together totalling 560 visitors, were given a tour of the Institute (Quetz, and others).

Approximately 2000 visitors (80% of whom were Spanish school children and 10% public Spanish public organisations and institutions) visited Calar Alto Observatory (Capel, and others).

7.1 Participation in Committees

R. Gredel: Member of the Calar Alto Program Committee

T. Herbst: Member of the Scientific Advisory Group for the ESA Darwin Project, the VLTI MIDI Teams, the LBT Near IR Spectroscopy Work Group; he organized the LBT Interferometry and Adaptive Optics meeting and participated in the Meeting of the Science Advisory Committee of the LBT Corporation.

Ch. Leinert: Member of the Appointment Committee of the University of Jena for the C3 position in astrophysics.

D. Lemke: Member of the Verbundforschung refereeing committee of the Federal Ministry of Education and Research and of the ISO Science Teams of the European Space Agency.

K. Meisenheimer: Member of the Arbeitsgemeinschaft Surveys der ESO.

R. Mundt: Member of the Calar Alto Program Committee

H.-W. Rix was main organizer of the German-American Frontiers of Science Meeting, that took place in Summer 2000 under the auspices of the Humboldt Foundation and the National Academy of Science; he was a member of the VLTI Steering Committee, of the Sloan Digital Sky Survey (SDSS) Council and of ESA’s Astronomy Working Group.

H.-W. Rix and A. Burkert were members of the “Denkschrift Astronomy” Committee of the Council of German Observatories.

7.2 Participation in international events and conferences

Arcetri Astrophysical Observatory, Florence, Italy, January: M. Haas (invited speaker).

American Astronomical Society, Austin, USA, January: S. Beckwith (talk)

Astronomical Colloquium of the Hamburg Observatory, January: Chr. Wolf (invited speaker)

Colloquium of the University of Chicago, January: A. Burkert

Friday Colloquium of the University Observatory, Munich, February: St. Phleps, (invited speaker)

Optical Astronomers’ Tea, Pasadena, USA, March: Chr. Wolf (talk)

VLT Opening Symposium, Antofagasta, Chile, March: R. Lenzen

Conference “Optical and Infrared Spectroscopy of Circumstellar Matter”, Tautenburg, March: T. Herbst (invited speaker), R. Gredel (invited speaker)

Colloquium at the University of Leiden, March: T. Herbst “Rencontres de Moriond - Building Galaxies: From the Primordial Universe to the Present”, Les Arcs, France, March: H.-W. Rix (invited speaker)

Conference “Imaging the Universe in Three Dimensions: Astrophysics with Advanced Multi-wavelength Imaging Devices”, Walnut Creek, CA, USA, March: T. Herbst (poster), Chr. Wolf (talk)

26th Saas Fee Advanced Course “Physics of Star Formation in Galaxies”, Les Diablerets, Switzerland, March: J. Woitas

Meeting on Galaxy Dynamics, Venice, Italy, March: N. Cretton (invited speaker)

Workshop on NGST Detectors, Baltimore, USA, April: S. Beckwith (talk)

Colloquium at the University of Tübingen, April: A. Burkert

New York University, New York, USA, April: S. Beckwith (talk)

Conference “Instrumentation at the Isaac Newton Group – The Next Decade”, Sheffield, UK, April: R. Gredel (invited speaker)

Physics Colloquium, University of Cologne, April: D. Lemke (invited speaker).

Astronomical Colloquium, University of Helsinki, Finland, April: D. Lemke (invited speaker).

Symposium at Cornell University to commemorate the 60th birthday of Yervant Terzian, Ithaca, USA, May: S. Beckwith (talk)

Euroconference “Stellar Clusters and Associations: Convection, Rotation, and Dynamos”, Palermo, Italy, May: D. Barrado y Navascués (talk and poster)

Institute for Astronomy, Cambridge, United Kingdom, May: A. Burkert

Workshop on ISO Polarization Observations, VILSPA, May: U. Klaas (talks).

Conference: “Working on the Fringe – An International Conference on Optical and IR Interferometry from Ground and Space”, Dana Point, USA, May: S. Ligori, S. Hippler, M. Kasper, I. Porro, M. Ollivier

Ringberg Meeting on Satellite Galaxies, June: A. Burkert (invited speaker)

Astronomical Colloquium, University of Basle, June: H.-W. Rix (invited speaker)

Heidelberg Colloquium of the Institute of Physics, University of Heidelberg, June: H.-W. Rix (invited speaker)

Conference “Gravitational Lensing: Recent Progress and

Future Goals'', Boston University, Boston, June: H.-W. Rix (talk)

Colloquium at the Max-Planck-Institut für Radioastronomie, Bonn, June: K. Meisenheimer (invited speaker)

Gordon Conference "Origins of the Solar System'', USA, June: Nelson (invited speaker and poster)

American Astronomical Society Meeting, Chicago, USA, June: D. Barrado y Navascués (Poster)

Conference "Star Formation'', Nagoya, Japan, June: A. Nelson and S. Ligori (poster)

Conference "Early Stages of Globular Clusters'', Lüttich, Belgium, July: A. Burkert (invited speaker)

IAP Conference "Dynamics of Galaxies'', Paris, July: A. Burkert

"Clustering at High Redshift'', Marseille, June/July: H.-J. Röser

Joint Astronomical Center Hilo, Hawaii, July: M. Haas (talk)

University of Honolulu, July: M. Haas (invited speaker)

SPIE Conference "Infrared Spaceborne Remote Sensing VII'', Denver, USA, July: D. Lemke (invited speaker)

Canterbury Conference on Wavefront Sensing and its Applications, Canterbury, UK, July: M. Kasper, S. Hippler, Th. Berkefeld, M. Feldt (talks)

AIP, Potsdam, July: M. Haas (invited speaker)

UCSC Summer Workshop Structures of dark matter halos, Santa Cruz, CA., USA, August: A. Burkert (invited speaker)

IAU Symposium 197, Astrochemistry: From Molecular Clouds to Planetary Systems, Sogwipo, S. Korea, August: R. Gredel (poster)

Ringberg-Symposium Galaxies in the Young Universe II, August: H.-J. Röser (SOC), Chr. Wolf (talk), B. v. Kuhlmann, K. Meisenheimer (SOC, talk), St. Phleps, H. Hetznecker, H. Hippelein (SOC), H.-W. Rix (talk)

Black Hole Workshop, Munich, September: H.-W. Rix (talk)

Astronomy Society, meeting, Göttingen, "ISO-Splintertreffen Galaxien im Infraroten'', September: D. Lemke (Organization); U. Klaas, L. Schmidtobreick (invited speakers); M. Geyer, B. v. Kuhlmann, M. Haas, S. Hotzel (poster); M. Kümmel, H. Hetznecker

International School of Space Science: High Resolution Observations in Astronomy, L'Aquila, Italy, September: S. Ligori

Conference "Modern Theories of Large Scale Structure'', Porto, September: H. Hetznecker (poster)

"Plasma Turbulence and Energetic Particles in Astrophysics'', Krakow, Poland, September: F. Heitsch

Workshop on Galactic Disks 99, organized by the MPIA and the Research Center for Astronomy and Applied Mathematics of the Academy of Athens, Heidelberg, October: H.-W. Rix (SOC, talk), Panos Patsis (talk), A. Burkert (talk), W. Dehnen (talk), P. Héraudeau (poster), R. Jesseit, T. Kranz (poster), S. Khochfar, T. Naab (poster), K. Wilke (poster)

In October R. Gredel was a visiting scholar of the Nagoya City University in Nagoya, Japan (talks in Nagoya University and Nobeyama Millimetre Observatory)

Milky Way Magnetic Field Mapping Mission (M4),

Workshop, Boston, USA, October: U. Klaas (talk).

Meeting in Honour of the 65th Birthday of Prof. Martinet, Geneva, Switzerland, October: N. Cretton

The Second Annual Meeting of the European Star & Planet Formation Network, Puerto de La Cruz, Tenerife, Spain, October: F. Heitsch, O. Kessel-Deynet, A. Burkert (talk),

The 11th Cambridge Workshop on Cool Stars, Stellar Systems and the Sun, Tenerife, Spain, October: C. Bailer-Jones, R. Mundt, D. Barrado y Navascués (talk and poster)

Division of Planetary Sciences of the American Astronomical Society annual meeting, Padua, Italy, October: P. Ábrahám (Poster)

Colloquium at the Institute for Astronomy, Cambridge, United Kingdom, November: A. Burkert

33. ESLAB Symposium: Star Formation from the Small to the Large Scale, ESTEC, Noordwijk, Netherlands, November: F. Heitsch; P. Ábrahám, S. Hotzel (poster).

Center Européen d'Astronomie, Saclay, November: M. Haas (invited speaker).

Darwin and Astronomy, Stockholm, November: T. Herbst (Member of the Scientific Organising Committee, talk)

XI. Canary Islands Winter School of Astrophysics Galaxies at High Redshift, November: B. v. Kuhlmann (poster)

Ringberg Symposium ISO surveys of a dusty universe, November: D. Lemke (SOC), U. Klaas, M. Stickel, K. Wilke (LOC); M. Stickel (invited speaker); M. Haas, S. Hotzel (Poster).

University of Padua, December: M. Haas (invited speaker).

Dynamic Models of Early-Type Galaxies, Strassburg, December: N. Cretton (invited seminar)

Teaching at the University of Heidelberg

Winter semester 1998/99:

I. Appenzeller: Interstellar Matter and Star Formation (lecture); A. Burkert: Formation and Development of Globular Clusters (lecture); A. Burkert: Structure, Kinematics and Dynamics of Stellar Systems (seminar); Ch. Leinert, D. Lemke, R. Mundt, H.-J. Röser: Astronomy and Astrophysics III (seminar); the astronomy lecturers: Astronomical Colloquium.

Summer semester 1999:

J. Fried: Galaxies (lecture); I. Appenzeller: Relativistic Astrophysics (lecture); H.-J. Röser: Galaxy Clusters (lecture); K. Meisenheimer: Galaxies of Extreme Redshift (lecture); Ch. Leinert, D. Lemke, R. Mundt: Astronomy and Astrophysics III (seminar); K. Meisenheimer: Stellar Dynamics (seminar); A. Burkert: Acceleration, Expansion and Radiation; Relativistic Particles in High Redshifted Radio Galaxies (seminar); H.-W. Rix: Cosmology (graduate course, October 1999); the astronomy lecturers: Astronomical Colloquium.

Public talks

S. Beckwith: Science with the NGST: 22. January, Space Telescope Science Institute, ADM Division, Baltimore; Space Science Update: 9th February, NASA Television Production on Protoplanetary Disks, Washington; Extrasolar Planetary Systems: 18th February, UVOIR Sub-committee of

the Investigation Committee Astronomy and Astrophysics, Baltimore; Wide Field Planetary Camera 3 IR: 22nd February, Origins Sub-committee, Cocoa Beach; From the Big-Bang to Life: 16th March, Kent Island Social Group, Kent Island; The Hubble Space Telescope: 15th April, Maryland Science Center Opening, Baltimore; Air, Space and the Search for Distant Planets: 20th April, American Geophysical Union, Annapolis; Astronomy from Space: 21st April, Boston Museum of Science, Boston; STScI and Goddard Space Flight Center: Opportunities for Science: 9th June, Goddard Space Flight Center, Greenbelt, USA

H. Elsässer: New Paths and Objectives in Astronomy: 19th January, Urania Berlin, 16th February, Wittheit Olbers Ges. Bremen, 6th December Univ. Hohenheim, Studium Generale; Current Questions on Extragalactic Research: 20th January, Wilhelm-Foerster Observatory, Berlin; Development and Formation of Galaxies: 2nd February, Physics Colloquium, Dresden; Structure and Development of the Universe: 22nd September, Science in the Town Hall, Dresden

J. Fried: Astrology – Science or Superstition? 15th December 1999, Rüsselsheim

T. Herbst: New Eyes for the New Millennium: A Revolution in Large Telescope Design, Max-Planck-Institut für Astronomie, Heidelberg, (course for teachers), October 1999

S. Hippler and S. Rabien: Sharp Images: Adaptive Optics with the Laser Guide Star. Radio program “Radius” of the Bayerisches Rundfunk (Bayern 2), 8th November 1999

K. Meisenheimer: The First Galaxies, Rüsselsheim, 17th September 1999

J. Staude: Formation of Stars and Planetary Systems, talks in Heidelberg, Heppenheim, Rüsselsheim, as well as five school talks in Dortmund and surroundings.

7.3 Publications

7.3.1 Publications

Ábrahám, P., A. Burkert, Ch. Leinert, D. Lemke and Th. Henning: Far-Infrared mapping of Herbig Ae/Be stars with ISO. In: Proceedings of conference “The Universe as seen by ISO”. ESA-SP-427, (Eds.) P. Cox and M. F. Kessel. Paris 1999, 265-268.

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Ábrahám, P., Ch. Leinert, J. Acosta-Pulido, L. Schmidtbreick and D. Lemke: Zodiacal light observations with ISOPHOT. In: Proceedings of conference “The Universe as seen by ISO”. ESA-SP-427, (eds.) P. Cox and M. F. Kessel. Paris 1999, 145-148.

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Acosta-Pulido, J. A., U. Klaas and R. J. Laureijs: The Starburst Galaxy NGC 6090: An ISO view. In Proceedings of conference “The Universe as seen by ISO”. ESA-SP-427, (eds.) P. Cox and M. F. Kessel. Paris 1999, (1999) 849-852.

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7.3.2 Diploma Theses

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7.3.3 PhD Theses

Eckardt, St.: Wirkung kosmischer Strahlung auf Infrarot-Detektoren in Astronomie-Satelliten und Charakterisierung einer Kamera für den Satelliten FIRST. Heidelberg 1999.

Kessel-Deynet, O.: Berücksichtigung ionisierender Strahlung im Smoothed-Particle-Hydrodynamics-Verfahren und Anwendung auf die Dynamik von Wolkenkernen im Strahlungsfeld massive Sterne. Universität Heidelberg 1999.

Wolf, C.: Vielfarben-Klassifikation in CADIS und die Suche nach Quasaren. Heidelberg 1999.

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7.3.4 Papers accepted for publication in refereed journals (at the end of the year of this report):

Abrahám, P., L. G. Balazs and M. Kun: Morphology and Kinematics of the Cepheus Bubble Astronomy and Astrophysics.

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Acosta-Pulido, J. A., C. Gabriel and H. O. Castañeda: Transient Effects in ISOPHOT Data: Status of Modelling Correction Procedures. *Experimental Astronomy*.

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Herbst, T.M.: First Results with a Wide-Field, Near-Infrared Integral Field Unit. In: *Imaging the Universe in Three Dimensions: Astrophysics with Advanced Multi-Wavelength Imaging Devices*, im Druck.

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Klessen, R. S. and A. Burkert: On the Formation of Stellar Clusters: Gaussian Cloud Conditions I. to appear in *The Astrophysical Journal Supplement Series*.

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Kochanek, C. S., E. E. Falco, C. D. Impey, J. Lehár, B. A. McLeod, H.-W. Rix, C. R. Keeton, J. A. Muñoz and C. Y. Peng: The Fundamental Plane of Gravitational Lens Galaxies and The Evolution of Early-Type Galaxies in Low Density Environments. *The Astrophysical Journal*.

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