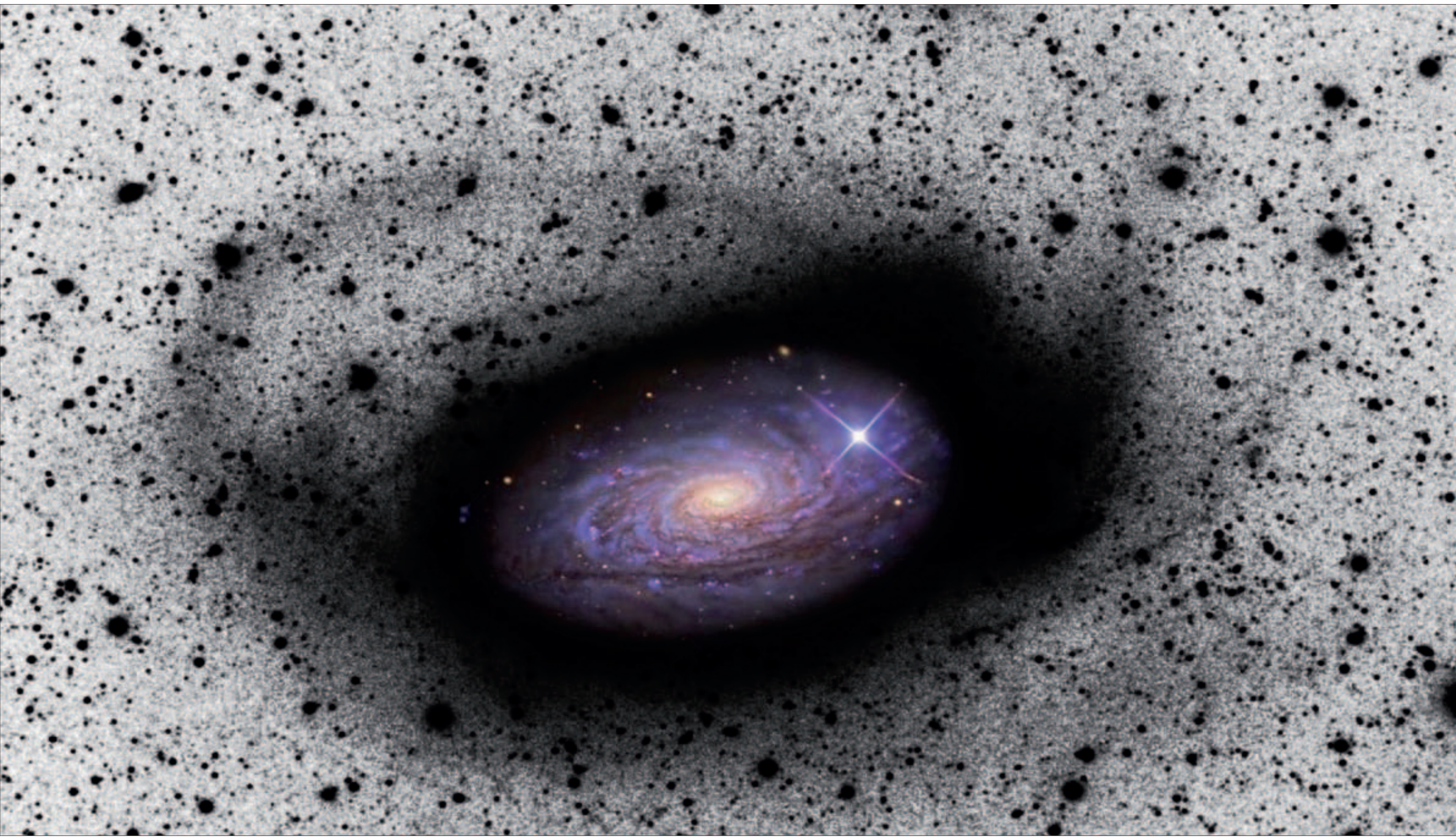
Max Planck Institute for Astronomy

Heidelberg-Königstuhl

Annual Report 2010



MAX-PLANCK-GESELLSCHAFT

Cover Picture:

Stellar streams around the galaxy M 63.

Remnants of a satellite galaxy that M 63 has swallowed. The central part is an ordinary positive image; in the outer regions, the negative of the image is shown. In this way, the faint structures that are the target of a new survey (see details in chapter II.5 at page 33) are more readily discerned.

This galaxy's distance from Earth is around 30 million light-years. The new survey has, for the first time, shown the presence of such tell-tale traces of spiral galaxies swallowing smaller satellites for galaxies more distant than our own "Local Group" of galaxies.

Credits: R. Jay Gabany (Blackbird Observatory) in collaboration with David Martínez-Delgado (MPIA and IAC) et al.

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Staff: By the end of 2010, a staff of 273 was employed at MPIA (including externally funded positions). This includes 243 scientists, of which 65 were junior and visiting scientists, and 64 were PhD students.

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Translations: Baker & Harrison, München
Printing: Druckerei & Verlag Steinmeier GmbH & Co. KG, D-86738 Deiningen
ISSN 1437-2924; Internet: ISSN 1617–0490

Contents

Preface

This Annual Report is intended for our colleagues worldwide as well as for the interested public and it describes the scientific activities at the Max Planck Institute for Astronomy (MPIA) in Heidelberg.

In addition to brief presentations of a broad range of current scientific results, we report in more depth on a few selected research areas at the MPIA, the instrumentation projects, and some other highlights of life at the institute.

The year 2010 has brought a rich scientific harvest on topics ranging from the structure of the universe to exoplanets.

There was also excellent, steady progress on crucial, observing facilities, including the LBT's first observations with adaptive optics and the start of regular science observations with Luci 1, second generation VLT and VLTI instruments, the start of the PAN-Starrs Survey, and JWST instrumentation as well as ongoing contributions for the European Extremely Large Telescope (E-ELT), laying the foundation for future astronomical discoveries.

Furthermore, the very successful first year of the Herschel mission with the perfect operation of the Pacs instrument was a special highlight.

On December 17, the topping out ceremony marked another important milestone in the construction phase of the "Haus der Astronomie", the new education and public out-reach facility being erected on the Königstuhl.

We hope that this Annual Review will give the reader a flavour of the research and work at the MPIA.

Thomas Henning, Hans-Walter Rix

Heidelberg, December 2011

I. General

I.1 Scientific Goals

Research at the Max Planck Institute for Astronomy (Fig. I.1) is aimed at exploring and understanding the nature and evolution of planets, stars, galaxies and the universe as a whole. This is pursued through the development and operation of telescopes and their instrumentation, by designing, executing and analysing observing programs and surveys, and by connecting to the physical nature of the observed phenomena through theoretical studies and numerical simulations. The MPIA focuses its observational capabilities on the optical and infrared spectral regions, taking a leading role in both ground-based and space-based instrumentation.

The research at the MPIA is organized within two scientific departments: Galaxies and Cosmology, and Planet and Star Formation. In addition to the staff in these departments, the Institute had in 2010 five independent Junior Research Groups (three Emmy Noether groups supported by the German Science Foundation DFG, and two groups supported by the Max Planck Society). Over the course of the year 2010, there were a total of 59 postdoctoral stipend holders, 89 PhD students, and 13 diploma and master's students and student assistants working at the institute. Strong ties exist between the Institute and the University of Heidelberg, with its Center for Astronomy (ZAH), both in teaching and research, for example through the International Max Planck Research School (IMPRS) for Astronomy and Cosmic Physics.

The main research fields of the two departments are complementary in both scientific and practical terms. Obviously, star formation is a critical aspect of the formation and evolution of galaxies, and the instrumentation capabilities required by both departments share strong commonalities: e.g. requirements for high spatial resolution, powerful survey capabilities, and the importance of access to the infrared and millimeter spectral regions.

Galaxies and Cosmology

The "Realm of Galaxies"

Shortly after the Big Bang, the Universe was rather "simple" and nearly homogeneous. Now it is beautifully complex, with rich "hierarchical" structure over a wide range of physical scales: from the filamentary distribution of galaxies on large scales (the "cosmic web") to galaxies themselves, down to clusters of stars, individual stars, and their planets. The formation of this wealth of structure appears to be driven by gravitational instabilities, but to make things "work" these instabilities must arise

Fig. I.1: The main building of the MPIA on the Königstuhl.

Credit: MPIA / K. Jäger

in good part from a dominant, but yet to be identified, dark matter component.

The galaxies we observe in the present-day universe represent a central layer in this hierarchical order, each consisting of millions to billions of stars, gas, and dust, all embedded in halos of dark matter. As Edwin Hubble already realized 80 years ago, these "island universes" do not show the full variety of morphology (or visual appearance) and structures that seem physically possible. On the one hand, the variety of galaxies seems vast: galaxies as an object class span ten orders of magnitude in their stellar masses, and the rate of new star formation varies similarly; the physical sizes of different galaxies still vary by a factor of 100. While some galaxies apparently do not have a black hole at their centers, in other galaxies this central black hole has the mass of more than one billion suns. On the other hand, observations have shown, particularly in the last 15 years, that only a small fraction of the possible combinations of the characteristic galactic quantities (stellar masses and ages, size, central black hole, etc.) are actually realized in the universe. Virtually all physical properties strongly correlate with all other properties: massive galaxies are large; massive galaxies contain virtually no young stars; the central black hole contains a constant mass fraction of the spherical star distribution ten million times its size. While spiral galaxies are the most common galaxy type, no such galaxy is among the most massive ones.

This means that the "realm of galaxies", as Hubble called it, shows a high degree of order. How this order developed from the random mass fluctuations existing after the Big Bang is a fundamental question of galaxy formation and a central issue of cosmology.

There are three broad lines of explanation for the limited variety in the zoo of galaxies: Either, observed galaxies represent the only stable configurations. Alternatively, the cosmological initial conditions only permit the formation of the galaxies we see. Or, the overall process of galaxy formation results in a limited set of outcomes because it is very much self-regulating.

What questions would we like to answer?

Many of the projects that the MPIA researchers are pursuing ultimately address when and where these three mechanisms play a role. Some of the specific questions being discussed by researchers in this department are:

- During which cosmological epoch did most of the stars form?
- Is cosmic star formation now coming to its end? Why has the star formation rate declined over the last six billion years?
- Which galaxies reside in which dark matter halos?
- How did the central black holes in galaxies form and grow? Why is it possible to predict the properties of the small-sized central black hole from the overall size of a galaxy?
- Which processes determine the structure and morphology of galaxies and when do these processes occur?
- What is the state of the interstellar medium, the raw material from which new stars form?
- What is the state of the intergalactic medium, in the space between galaxies, where most of the atoms in the univere reside?
- Can the various observations be understood ab initio within a comprehensive model?
- How did the Milky Way, our Rosetta Stone of galaxy evolution, form?

What do we do to find the answers?

The approaches used at the MPIA to tackle these questions comprise three aspects: the detailed study of galaxies in the present-day Universe; the direct study of galaxies at earlier cosmic epochs through the observation of distant (high-redshift) objects; and the comparison of observations with physical models. The observational capabilities for the field require survey telescopes, large telescopes for sheer photon collecting power on faint sources, and particular techniques such as Adaptive Optics and Interferometry to achieve high spatial resolution. Comprehensive studies of galaxy evolution require observations from the X-rays to the radio wavelengths.

The MPIA has been an important partner in several of the surveys that have brought, or promise to bring, breakthroughs in these areas: the Sloan Digital Sky Survey (SDSS) and Segue for the Milky Way and Local Group, the Pan-Starrs-1 survey which has successfully started in 2010 – and since 2008, this suite was complemented by the completion of the LBC cameras of the LBT; the 2.2 m telescope on La Silla has enabled the Combo-17 galaxy evolution survey; the VLT and the LBT are used to follow-up this survey work; the Irac and Mips instruments on the Spitzer Space Telescope; and the Pacs Instrument of the Herschel mission to study star formation and the interstellar medium, complemented by the VLA, the Plateau de Bure Interferometer, Apex and soon Alma at radio and sub-millimeter wavelengths. The Galaxies and Cosmology department truly carries out multi-wavelength astrophysics.

Planet and Star Formation

The link between stars and galaxies

The formation of stars is a fundamental process in the Universe, shaping the structure of entire galaxies and determining their chemical state. The formation of individual stars can be best studied in nearby molecular clouds. The study of star formation in other galaxies allows us to understand this process under physical conditions which can be very different from those in the Milky Way. Our studies of star formation in the Magellanic Clouds allow an investigation of the effect of metallicity on the star formation process, which is certainly an important factor in understanding star formation in the early Universe.

Stars are born in the dense and cold cores of molecular clouds, which become gravitationally unstable and, in general, fragment to form binaries and multiple stellar systems. The role of magnetic fields or turbulence in controlling the onset of star formation remains one of the open key questions. This question is immediately related to the shape of the initial (sub-) stellar mass function in different environments. Dynamical interactions in multiple systems may be a crucial factor for the formation of Brown Dwarfs. Massive star formation takes place in clusters, leading to complex star-forming regions. The rapid evolution of massive protostars and the associated energetic phenomena provide an enormous challenge in identifying the formation path of massive stars.

Looking behind the curtain…

The earliest phases of star formation are obscured by enormous amounts of dust and gas and can only be detected by sensitive far-infrared and (sub-) millimeter observations. At later evolutionary stages, the objects "glow" at near- and mid-infrared wavelengths, and finally become visible at optical wavelengths. Our observing programs cover a wide range of wavelengths with a special emphasis on infrared and (sub-) millimeter observations.

The formation of planets and planetary systems is a natural by-product of low-mass star formation. Because of angular momentum conservation, accretion of matter onto the central protostar happens predominantly through a circumstellar disk. Disks around T Tauri stars are the natural birthplaces of planetary systems, resembling the solar nebula 4.5 Gyr ago. During the active accretion phase, bipolar molecular outflows and ionized jets are produced, which in turn play an important role in the evolution of star-disk systems. We are presently starting to use protoplanetary disks as laboratories for understanding the formation of our own solar system and the diversity of other planetary systems detected so far.

The research of the Planet and Star Formation department is focused on the understanding of the earliest phases of stars, in both the low and high stellar mass regime. Observations with space observatories such as Spitzer, HST and Herschel, as well as ground-based infrared and (sub-) millimeter telescopes, allow the detection and characterization of massive protostars and their subsequent evolution. The vigorous use of submillimeter facilities is preparing the department for the Atacama Large Millimeter Array (Alma), which will soon commence operation.

The investigation of Brown Dwarfs, which were first detected in 1995, is another important research topic. How do Brown Dwarfs form? Are young substellar objects also surrounded by disks? What is the binarity fraction and the exact mass of these objects? What is the composition of their atmospheres? These are among the burning questions which are attacked by MPIA scientists.

The formation of planetary systems and the search for other planets

With the detection of the first extrasolar planets, the study of planet formation in protoplanetary disks entered a new phase of explosive growth. The department is well-positioned to play an important role in these studies, with a combination of infrared and submillimeter observations, numerical (magneto-) hydrodynamical simulations, and radiative transfer studies. Imaging with the Hubble Space Telescope and the wealth of data from the Spitzer Telescope is providing new insights into the earliest stages of planet formation. Improved spatial resolution from our adaptive optics program, infrared interferometry with large telescopes and long baselines, and the use of millimeter interferometers provide insights into disk structure and evolution on spatial scales relevant to planet formation. Gas evolution in disks is studied by high-resolution infrared spectroscopy and the accretion behaviour by multi-object spectroscopy.

We have started new observing programs to search for extrasolar planets through direct imaging, the transit technique, and astrometry. With the Spectral Differential Imaging facility (SDI) at the VLT, we provided a new mode for high-contrast imaging with the adaptive optics instrument Naco. This system presently outperforms any other similar device in the world and was paving the way for the development of Eso's Sphere instrument, where MPIA is Co-PI institute. The department actively participates in the planet search program Seeds with the Subaru telescope on Mauna Kea (Hawaii).

The theoretical program of the PSF department focuses on complex numerical simulations of protoplanetary disk evolution, including the interplay between radiation, dynamics, chemistry, and grain evolution. The study of the formation of massive stars constitutes another topic for theoretical studies. Multi-dimensional radiative transfer codes, both for molecular lines and the dust continuum, have been developed in the department. These theoretical studies are also well integrated with the various observational key projects.

The understanding of many of the microphysical processes and the composition of dust and gas requires dedicated laboratory studies. Such a laboratory astrophysics unit is part of the Planet and Star Formation department, and is located at the Institute for Solid-State Physics of the University of Jena. This group investigates the spectroscopic properties of nanoparticles, as well as molecules, especially PAH's, in the gas phase.

I.2 Observatories, Telescopes, and Instruments

The MPIA has been a key driver and partner in the construction and operation of two large ground-based observatories. During the 1970s and 1980s the construction of the Calar Alto Observatory, still the largest observatory on the European continent, had been the central focus of the MPIA, and the 2.2 and 3.5 m telescopes are scheduled for competitive observing programs. Since 2004 the observatory is jointly operated as Centro Astronomico Hispano Aleman (CAHA) by the Max Planck Society, represented by the MPIA, and the Consejo Superior de Investigaciones Científicas (CSIC), represented by the Instituto de Astrofísica de Andalucía (IAA), as an organization of Spanish law. Since 1997, the MPIA has been the coordinating institute for the German participation in the Large Binocular Telescope (LBT) on Mt. Graham near Tucson, Arizona. By the end of 2007, the second prime-focus camera was installed. The camera is now used for regular science programs. The year 2008 has seen the installation and the beginning of the commissioning of the LUCI instrument, jointly built by the State Observatory in Heidelberg, the MPIA, the MPE, the Ruhr University in Bochum and Fachhochschule in Mannheim. Science demonstration observations with this near-infrared multi-object spectrometer have commenced in December 2009 and already at the beginning of 2010 the first excellent spectra and images have been published. Furthermore, the first adaptive secondary mirror for the LBT started its operation and hence the first "sharper than Hubble" near infrared LBT-images could be released. The MPIA also uses its 2.2 m telescope on La Silla, Chile, operated by the European Southern Observatory (ESO). As of April 1st 2009 in a new agreement between the MPG and ESO, the amount of time available at this telescope for MPG researchers has been increased from 25 to 75 percent.

The MPIA has a prominent and successful tradition of developing and building instruments for ground-based and space-based astronomical observations. Such observations are, almost by necessity, complementary.

Fig. I.2: Aereal view of the Calar Alto Observatory.

Credit: MPIA

Ground-based telescopes usually have larger mirrors and therefore more light-gathering power than space telescopes. By using cutting-edge techniques such as adaptive optics and interferometry – which the MPIA has played a leading role in developing – they can also achieve higher angular resolution. Space telescopes, on the other hand, are the only way to carry out observations in wavelength regions where our atmosphere absorbs the radiation or generates a bright background, as is the case, for example, in wide regions of the infrared spectral regime.

Since the pioneering days of infrared astronomy in the 1970s, the MPIA has been a leading instrument developer for this field of astronomy. In particular, the construction and implementation of Isophot, one of four scientific instruments aboard Iso, the first Infrared Space Observatory of the European Space Agency Esa, was led by the MPIA. From 1996 to 1998, it acquired excellent data, particularly in the previously inaccessible far-infrared range. The knowledge gained with Iso was the basis for MPIA's prominent role in ongoing space projects such as the Herschel Space Observatory and the James Webb Space Telescope (JWST). Astronomers at the MPIA are also actively participating in legacy science programs with the Spitzer Infrared Observatory.

At the end of 2009 Herschel has provided the first data obtained within a number of key science programs with MPIA participation. During 2010 and within the regular operation, the first scientific papers based on excellent Herschel data (see also III.1 of this annual report) have been published in a dedicated Astronomy & Astrophysics special issue. The new generation of instruments for 8m-class telescopes and space missions are too large and expensive to be built by a single group, such as the MPIA. At present, the Institute is therefore participating in, or leading a number of international collaborations for building scientific instruments for new large telescopes, thereby gaining access to the world's most important observatories. An example in the southern hemisphere is the Eso Very Large Telescope (VLT) in Chile, with its four 8 m telescopes that can be linked to form a powerful interferometer. In the northern hemisphere, the MPIA is participating in the Large Binocular Telescope (LBT) in Arizona. This extraordinary telescope is equipped with two mirrors of 8.4 m diameter each, fixed on a common mount, making it the world's largest single telescope. With the current routine scientific use of the two prime focus cameras and the beginning of observations with the near-infrared multi-object spetrograph Luci 1 in December 2009, the LBT has become a productive world-class observatory. In 2007, MPIA became the University of Hawaii's largest Partner in the international Pan-Starrs1 (PS1) project, which grants full access rights to the data from a 1.8m wide-field telescope on Haleakala/Maui (Hawaii) with a 1.4 Gigapixel camera – the largest digital camera ev-

Fig. I.3: The Very Large Telescope at Cerro Paranal, in the Northern Chilean Andes.

Credit: Eso

er built. In 2010 PS1 provided MPIA scientists with the first regular survey data.

These collaborations enable MPIA astronomers to observe the northern and the southern sky with firstclass telescopes. At the same time the MPIA is participating in studies for the instrumentation of next-generation large telescopes, the so-called Extremely Large Telescopes (ELT).

Instrumentation for Ground-based Astronomy

The currrent activities of the MPIA in the area of ground-based instrumentation concentrate on interferometric instruments for the ESO VLT Interferometer (VLTI), high-fidelity imaging instruments for the LBT and the VLT, and survey instruments for Calar Alto. The MPIA is also involved in studies for future instruments for the European ELT (E-ELT).

VLTI instrumentation

In September 2008, the differential delay lines for the dual-feed VLTI system PRIMA were installed on Cerro Paranal, Chile. These units were built by the MPIA together with Geneva Observatory and Landessternwarte Heidelberg. PRIMA is now in its active commissioning phase. In the related science project ESPRI, the differential delay lines will be used in the combined K-band light from two 1.8 m VLT Auxiliary Telescopes, in order to measure the separation of a stellar target from a reference star with micro-arcsecond precision. The goal is the dynamical determination of the masses of extrasolar planets by precise astrometric measurements of the orbital reflex-motions of planetary host stars.

MPIA is participating in the second-generation VLTI projects MATISSE and GRAVITY. MATISSE is a successor of the very successful MIDI instrument built by the MPIA which has been in operation on Paranal since September 2003. The MATISSE consortium consists of nine institutes led by the Observatoire de la Côte d'Azur. MATISSE will combine the light from all four VLT 8.2 m telescopes in the mid-infrared for high spatial resolution image reconstruction on angular scales of 10 – 20 milliarcseconds. The scientific applications range from studies of Active Galactic Nuclei (AGN) to the formation of planetary systems and of massive stars, and the study of circumstellar environments.

GRAVITY is the successor of PRIMA. Like MATISSE it will combine four VLT 8.2 m telescopes, but in the near-infrared. The GRAVITY consortium is led by MPE Garching; the partners include MPIA, l'Observatoire de Paris, and the University of Cologne. Assisted by a high-performance adaptive optics system, GRAVITY will provide precision narrow-angle astrometry and phase referenced imaging of faint objects over a field of view of 2″. This will permit astronomers to study motions to within a few times the event horizon size of the massive black hole in the Galactic Center, and potentially test General Relativity in its strong field limit. Other applications are the direct detection of intermediate mass black holes in the Galaxy, dynamical mass determinations of extrasolar planets, the origin of protostellar jets, and the imaging of stars and gas in obscured regions of AGNs, star forming regions, or protoplanetary disks.

High-resolution cameras

After its integration at MPIA, LUCI 1, the first of two identical mid-infrared cryogenic imaging cameras and multi-object spectrographs for the LBT, was shipped to Mt. Graham in August 2008, followed by phases of installation and commissioning. This instrument built together with the Landessternwarte Heidelberg, the MPE Garching, the University of Bochum, and the Fachhochschule for Technology and Design in Mannheim, has become ready for scientific exploitation in December 2009. It provides a $4' \times 4'$ field-of-view in seeing limited mode. Already at the beginning of 2010 the first excellent spectra and images have been published. With the adaptive secondary mirrors (the first one was installed at the LBT in 2010), diffraction-limited performance can be expected for the two LUCI instruments over a field of about $0\farcm5 \times 0\farcm5$. Adaptive optics will also permit users to achieve spectral resolving powers of several tens of thousands. Scientific applications for the multi-mode LUCI instruments are many, including studies of star formation in nearby galaxies.

The largest instrumentation project at the MPIA is the near-infrared beam combiner LINC-NIRVANA for the LBT, which presently is being assembed at the institute. As the PI institute, the MPIA leads a consortium with the Italian Observatories (INAF), the MPIfR Bonn, and the University of Cologne. LINC-NIRVANA is currently undertaking integration and testing at the MPIA as the various subsystems provided by the different project partners are being delivered. By coherent combination of the two LBT primary mirrors via Fizeau interferometry, LINC-NIRVANA will provide diffraction-limited imaging over a $10\farcs05 \times 10\farcs05$ field of view in the 1 – 2.4 μm regime, with the spatial resolution of a 23 m-telescope. Multi-conjugated adaptive optics with up to 20 natural guide stars will ensure large sky coverage. Due to the panoramic high-resolution imaging and astrometric capabilities of LINC-NIRVANA, scientific applications range from supernova cosmology, galaxy formation, and extragalactic stellar populations and star formation, to extrasolar planets, stellar multiplicity, the structure of circumstellar disks, and the imaging of solar-system planets and their atmospheres.

As Co-PI institute in a consortium with the Laboratoire d'Astrophysique de l'Observatoire in Grenoble, the Laboratoire d'Astrophysique in Marseille, ETH Zürich and the University of Amsterdam, the MPIA coleads

Credit: LBTO

Fig. I.4: The building of the Large Binocular Telescope (LBT) on Mt. Graham, Arizona.

the development of Sphere, a VLT instrument specialized for the imaging of Jupiter-like extrasolar planets. To overcome the huge brightness contrast between the planet and its host star, Sphere will use eXtreme Adaptive Optics (Xao), coronography, and three differential imaging-capable focal plane subinstruments that will, respectively, employ polarimetry in the visual, dual imagery in the near-infrared, and integral field J-band spectroscopy.

Survey instrumentation

The current workhorse for MPIAs survey efforts in the near infrared at Calar Alto is the Omega2000 near-infrared imager, in operation at the prime focus of the 3.5 m telescope since 2003. It provides a field of view of $15.'5 \times 15.'4$, and z- to K-band sensitivity.

The successor of Omega2000 will be Panic, the Panoramic Near-infrared Camera, which is a wide-field general purpose instrument for the Calar Alto 2.2 m telescope. Panic is a joint development of the MPIA and the Instituto de Astrofísica de Andalucía. With four Hawaii2-RG detectors, it will provide a field of view of $30' \times 30'$. Surveys of extragalactic, galactic, and solar system objects will be possible as well. Some of the numerous possible science cases are gamma-ray burst hosts, supernovae, distance scales, high-redshift quasars, accretion disks, post AGB-stars, and X-ray binary counterparts.

MPIA has also build Laiwo, the Large Area Imager for the Wise Observatory (Israel). It is an optical camera that was re-installed at the observatory's 1 m telescope in fall 2008. A mosaic of four CCD detectors with $4\,K \times 4\,K$ pixels each provides a field of view of one square degree. The main scientific application is the photometric search for transiting extra-solar planets of Jupiter size.

The Hat-South project is a network of 24 small-sized automated telescopes with the goal to survey a large number of nearby stars to search for transiting extrasolar planets. These telescopes are located at three sites: Las Campanas in Chile, the Hess site in Namibia, and Siding Springs in Australia. MPIA is responsible for the site preparation and operations of the Namibian node. The survey is expected to detect about 25 planets per year. The Hat-South project is a collaboration between Harvard, the Australian National University, and MPIA.

Instruments for next generation telescopes

In preparation for the future, MPIA has participated in two studies for instruments for the 42 m E-ELT telescope: Metis and Micado. The Metis concept is a thermal/mid-infrared imager and spectrograph whose wavelength coverage will range from 3 – 14 microns. A wide range of selectable resolving powers is planned. Adaptive optics will permit diffraction-limited observations. Science cases are conditions in the early solar system, formation and evolution of protoplanetary disks, studies of the galactic center and of the luminous centers of nearby galaxies, high-redshift AGNs and high-redshift gamma ray bursts.

In December 2008, several concepts of the MICADO study were evaluated and down-selected for a phase A study. MICADO is a near-infrared imaging camera with multi-conjugated adaptive optics that will provide a spatial resolution exceeding that of the James Webb Space Telescope (JWST) by a factor of 6 to 7. It will have a sensitivity down to 29 mag in bandpasses from I to K. Applications range from young stellar objects in our galaxy to star formation in high-redshift galaxies. The achievable astrometric precision will further advance studies of stellar orbits around the black hole in the galactic center and of the proper motions of globular clusters in the galactic halo. With MICADO, detailed mapping will be possible on scales as small as 80 pc of the structure, the stellar populations, and the interstellar dust distribution in galaxies with redshifts $z<1$. In 2010, an ESO commission led by MPIA already finished the search for the E-ELT site. It will be the mountain Cerro Armazones in Chile's Atacama Desert (after intensive studies of various suitable places in the world including Spain, Argentina, and Tibet).

Instrumentation for Space-based Astronomy

Europe's new far infrared and submillimetre space observatory HERSCHEL has started its four year long mission with a picture-perfect launch aboard an ARIANE-5 rocket on 14^{th} May 2009. The MPIA has been one of the major partners in the development of the PACS instrument which will enable imaging and spectroscopy in the wavelength range from 60 to 210 mm with unprecedented sensitivity and spatial resolution.

The MPIA has been responsible for delivering the PACS focal plane chopper and for characterizing the large Ge:Ga spectrometer cameras and their –270 °C readout electronics.

After successful delivery and check-out of the PACS hardware contributions, MPIA has been heavily involved in many PACS Instrument Control Center tasks. The Instrument Control Centre (ICC), located at the PI institute MPE in Garching, has the responsibility for operations, calibration and data reduction of the PACS instrument. MPIA is one of four institutes of the PACS consortium which are main manpower contributors to the PACS ICC. MPIA has coordinated a large number of tasks for the calibration of the PACS instrument and has been responsible for establishing the PACS performance

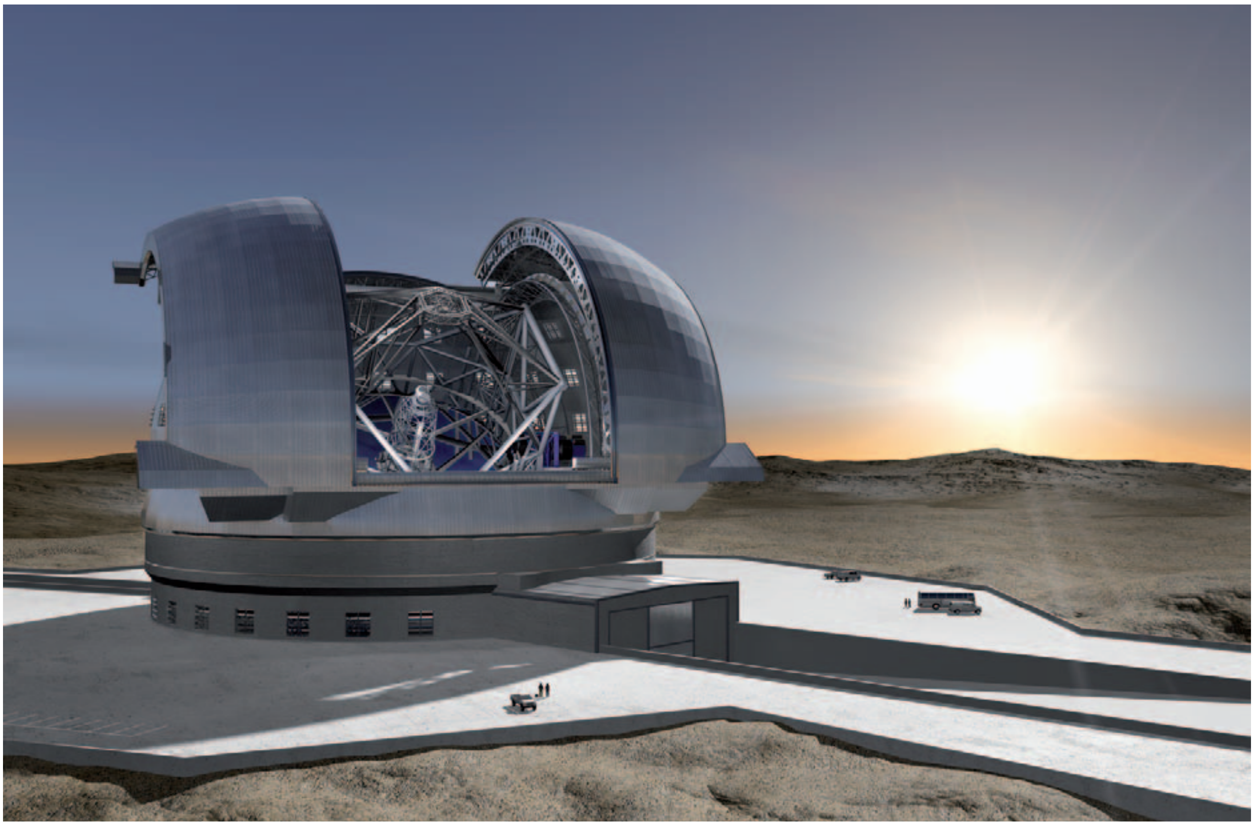


Fig. I.5: The European Extremely Large Telescope, E-ELT.

Credit: ESO

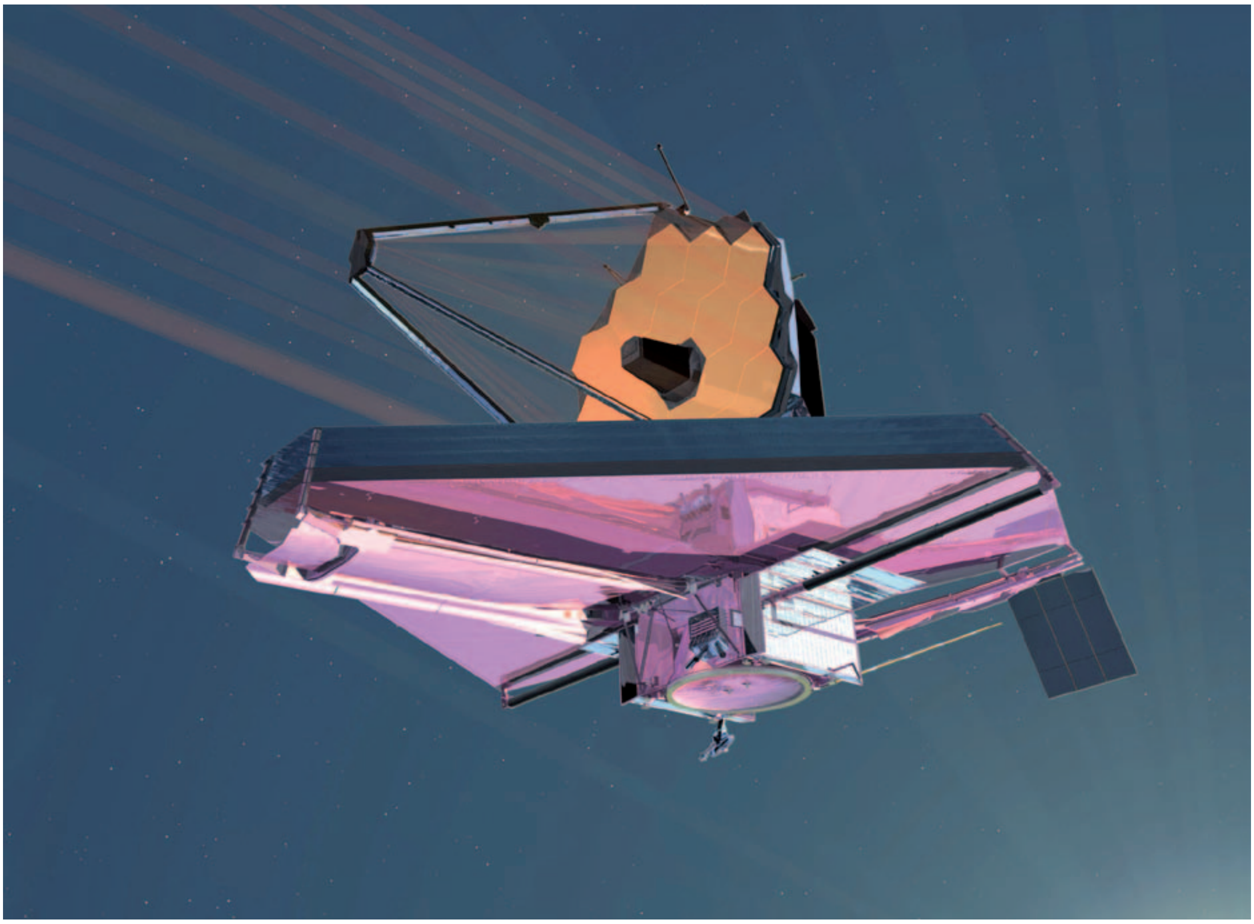
Credit: ESA

Fig. I.6: On May 14th, 2009, after more than ten years of development, HERSCHEL was liftet into space to start its mission. In chapter III.1 members of the PACS team at MPIA present first scientific result.

verification phase plan and the central PACS calibration document. In particular, the MPIA team has exclusively carried out the detailed mission planning of all PACS performance verification phase operational days, utilizing dedicated software tools, and has delivered the observational data bases to the HERSCHEL Science Center at ESAC in Villafranca (Spain) and the Mission Operations Center at ESOC in Darmstadt (Germany). The MPIA team had build up a corresponding calibration plan for HERSCHEL's routine phase and also ensured the optimum inflight setup of the Ge:Ga spectrometer detector arrays following a procedure developed in the MPIA space laboratory (see chapter III.1 for details about HERSCHEL and the excellent scientific data obtained in 2010 during the regular mission).

The MPIA is the leading institute in Germany for the development of instrumentation for the James Webb

Fig. I.7: Design model of the James Webb Space Telescope (JWST), with its large segmented primary mirror and characteristic sun shield.



Credit: NASA

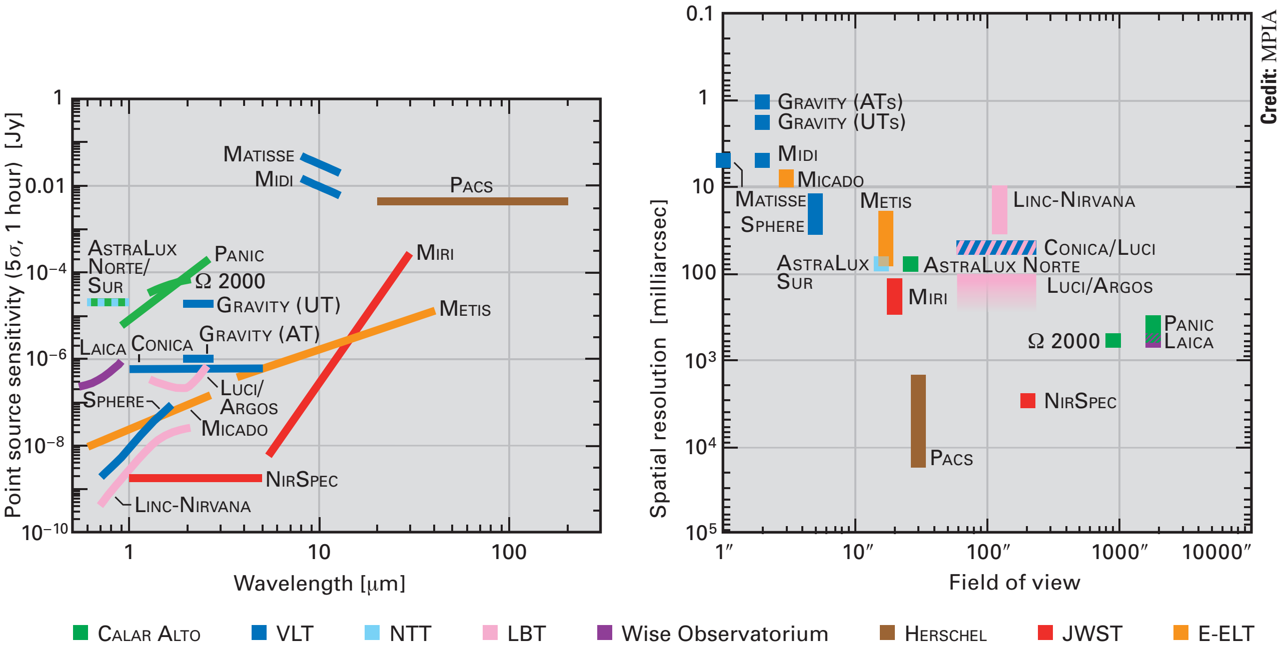


Fig. I.8: Capabilities of MPIA's major instruments. *Left:* sensitivity as a function of wavelength. *Right:* spatial resolution as a function of field of view.

Space Telescope (JWST, Fig. I.7), to be launched in this decade as the successor to the Hubble Space Telescope. JWST will be equipped with a folding primary mirror with a diameter of 6.5 m and four science instruments. As a member of a European consortium, MPIA is responsible for the development of the cryogenic wheel mechanisms required for precise and reliable positioning of the optical components in JWST's mid-infrared instrument Miri and is also leading the electrical system engineering of this instrument. Miri is designed for the wavelength range from 5 to 28 micron, and consists of a high-resolution imager and a spectrometer of medium resolving power.

In 2009 the flight model of the filter wheel mechanism was delivered for integration into the imager section of the Miri instrument.

The MPIA also provides critical components for the second JWST instrument mainly developed in Europe, the near-infrared multi-object spectrograph NirSpec. This contribution, as well as our participation in the NirSpec science team, will provide the astronomers at MPIA with further excellent opportunities for powerful infrared observations. For the development of the precision optics of Miri and NirSpec, the MPIA is closely cooperating with Carl Zeiss Optronics, Oberkochen, and Astrium GmbH, Ottobrunn and Friedrichshafen. With the end of 2010, all tasks regarding the cryogenic mechanisms were successfully finished and they were integrated into Miri and NirSpec.

The MPIA is also leading a major data analysis aspect of Esa's Gaia project, a space observatory scheduled for launch in 2012. Gaia will be the successor to the Hipparcos astrometry satellite, exceeding the latter's sensitivity by several orders of magnitude. The satellite will measure positions, magnitudes, and radial velocities of one billion stars, in addition to numerous galaxies, quasars and asteroids. The telescope will provide photometric data in 15 spectral bands as well as spectra in a selected spectral range. Unlike Hipparcos, Gaia does not need to be provided with an input catalogue, but will measure systematically all accessible objects. Automatic object classification will thus be of major importance for data analysis. Concepts for coping with this demanding task are being developed at the MPIA (supported by a grant from DLR).

MPIA is involved in the mission studies within the Esa Cosmic Vision program. Euclid has the goal of mapping the geometry of the dark Universe by studying the distance-redshift relationship and the evolution of cosmic structures. To this end, the shapes and redshifts of galaxies and galaxy clusters will be measured out to redshifts $z \approx 2$, that is, to a look-back time of 10 billion years, thereby covering the entire period over which dark energy played a significant role in accelerating the expansion of the Universe. The observing strategy of Euclid will be based on baryonic acoustic oscillations measurements and weak gravitational lensing, two complementary methods to probe dark energy. The Euclid survey will produce 20 000 deg^2 visible and near-infrared images of the extragalactic sky at a spatial resolution of 0.030 arcsec. It will also yield medium resolution ($R = 400$) spectra of about a third of all galaxies brighter than 22 mag in the same survey area.

Plato (PLAnetary Transits and Oscillations of stars) is another Esa Cosmic Vision mission. Its primary goal is to provide the basis for statistical analyses of exoplanetary systems around stars that are bright and nearby enough to allow for simultaneous or later detailed studies of their host stars. PLATO will observe 20 000 dwarf stars with a photometric precision better than 27 ppm/hour of observing and more than 250 000 stars to somewhat lower precision. Seismic analysis will lead to the determination of stellar and planetary masses with up to one percent precision, and the detection of Earthsized planets, with age determinations to within several 100 million years. PLATO will provide a very wide field of view (550 square degrees). The required short focal length led to the concept of a bundle of 42 small telescopes, each of which has a collecting area of 0.01 m^2.

SPICA, the Space Infrared Telescope for Cosmology and Astrophysics, is the third astronomy mission of ESA's Cosmic Vision in which MPIA is participating in the study phase. The mission is planned to be the next space astronomy mission observing in the far infrared after HERSCHEL. The mission is planned to be launched in 2017 and will feature a cold 3.5 m telescope. This large cold aperture will provide up to two orders of magnitude sensitivity advantage, mostly for spectroscopic observations, over existing far-infrared facilities and HERSCHEL. SPICA is led by the Japanese Space Agency JAXA. Europe has proposed to participate with a SPICA Far Infrared Instrument called Safari, the telescope mirror, and support of the ground segment.

During 2010, the described missions were still within the shortlist of the first two mid-size missions to be launched in 2017 and 2018 within the Cosmic Vision Program.

Fig. I.8 gives an overview of the major instruments which are already working or are about to be put into operation. Sensitivity is shown as a function of wavelength (*left*), and spatial resolution as a function of the size of the field of view (*right*).

I.3 National and International Collaborations

MPIA is strategically well-placed: Heidelberg has become one of Germany's foremost centers of astronomical research. Cooperation with the High-energy Astrophysics Department of the MPI für Kernphysik, the new Heidelberg Institute for Theoretical Studies (HITS), and with the institutes of the Center for Astronomy Heidelberg (ZAH), established in 2005, is manifold: the ZAH consists of the Landessternwarte, the Astronomisches Recheninstitut, and the Institut für Theoretische Astrophysik at the University. Also, the "International Max Planck Research School" for Astronomy and Cosmic Physics (IMPRS, see Section I.4) is run jointly by the Max Planck Institutes and the University.

Nationally, cooperation with the MPI für extraterrestrische Physik in Garching and the MPI für Radioastronomie in Bonn, as well as with numerous other German institutes, whose locations are shown in Fig. I.8, is extensive.

The establishment of the German Center for Interferometry (Frontiers of Interferometry in Germany, or FrInGe), located at the MPIA, also emphasizes the Institute's prominent role in Germany in this innovative astronomical technique. The goal is to coordinate efforts made by German institutes in this field and to accomo-

Fig. I.9: Position of the partner institutes of the MPIA in Germany.

Credit: Mountain High maps

date the interests of the German astronomical community in the European Interferometric Initiative. Another specific goal is the preparation of the next generation of interferometric instruments. This includes the preparation of second-generation instruments for VLTI, such as Matisse – an imaging interferometer consisting of four telescopes – and Gravity. Further tasks are: participation in the definition of new imaging capabilities of the VLT interferometer. FrInGe, together with other interferometric centers in Europe, is partaking in the establishment of the European Interferometry Initiative. The long-term perspective is to establish a European interferometric center for the optical and infrared wavelength region. In addition to MPIA, the following institutes are participating in FrInGe: the Astrophysikalisches Institut Potsdam, the Astrophysikalisches Institut der Universität Jena, the Kiepenheuer Institut für Sonnenphysik in Freiburg, the MPI für Extraterrestrische Physik in Garching, the MPI für Radioastronomie in Bonn, the University of Hamburg, the I. Physikalisches Institut der Universität Köln, and the Universities of Kiel and Munich.

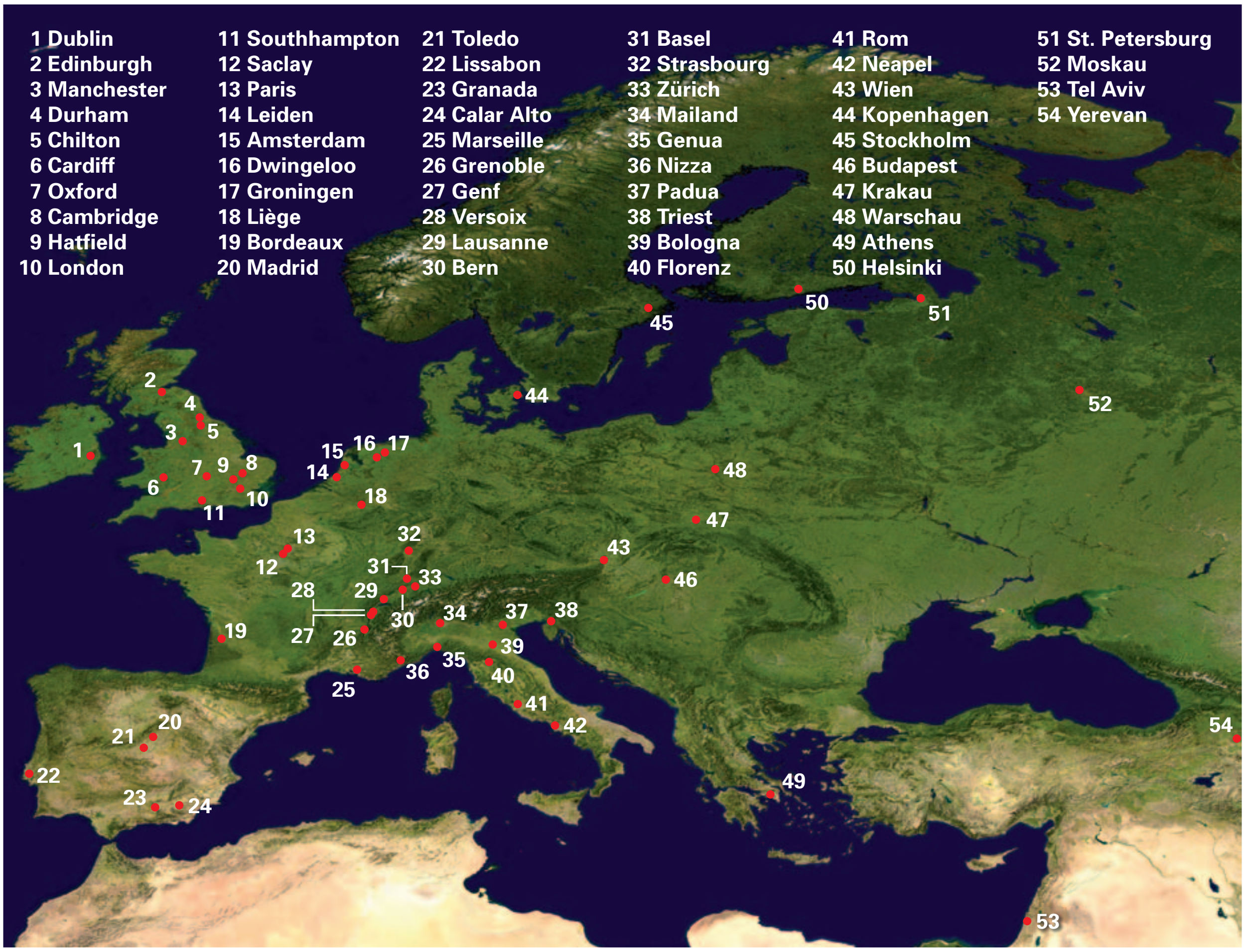
The MPIA is participating in a number of EU-networks and worldwide collaborations, in part as project leader. These include:

Opticon: A network of all operators of major telescopes in Europe, financed by the European Union. Its main goal is to optimize use of scientific technical infrastructure, in order to increase scientific results and reduce costs. Opticon's other main goal is to coordinate technology development for the next generation of ground-based telescopes.

Espri (Exoplanet Search with Prima): This project aims at carrying out the first systematic astrometric planet search with a measurement accuracy of 10–20 microarcseconds. For this purpose, we have built, in collaboration with Eso, the Landessternwarte Heidelberg, and the Geneva Observatory in Switzerland, differential delay lines for the Prima facility at the VLTI. Our consortium is also developing the astrometric data reduction software.

Cid: The "Chemistry In Disks" project is a joint collaboration with Bordeaux, Jena and Iram (Grenoble). The major goal of Cid is the study of physical structure and chemical composition of protoplanetary disks at various evolutionary stages. We focus on a sample of nearby bright protoplanetary disks orbiting low-mass (TTauri) and intermediate-mass (Herbig Ae) stars. For that, we employ multi-molecule, multi-line observations with the

Fig. I.10: Position of MPIA's international partner institutes. See also on the following page.



Credit: Nasa "Blue Marble"

Plateau de Bure interferometer and the IRAM 30 m antenna, followed by comprehensive data analysis and theoretical modeling.

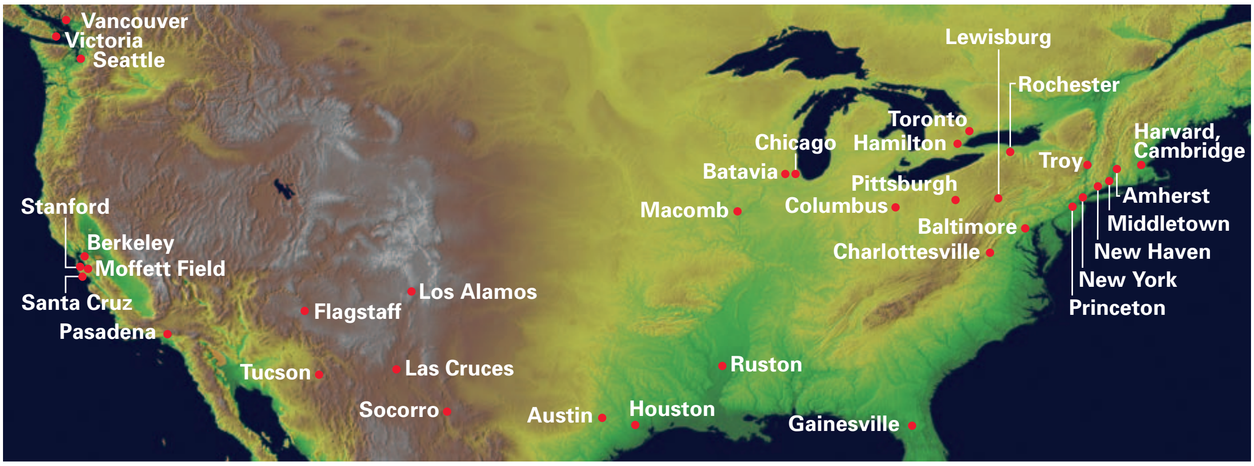
SEEDS: This is an imaging survey using the SUBARU telescope. The main goal is to search for giant planets and protoplanetary/debris disks around 500 nearby stars of solar type or other more massive young stars. This is a collaboration between NAOJ, Princeton and MPIA.

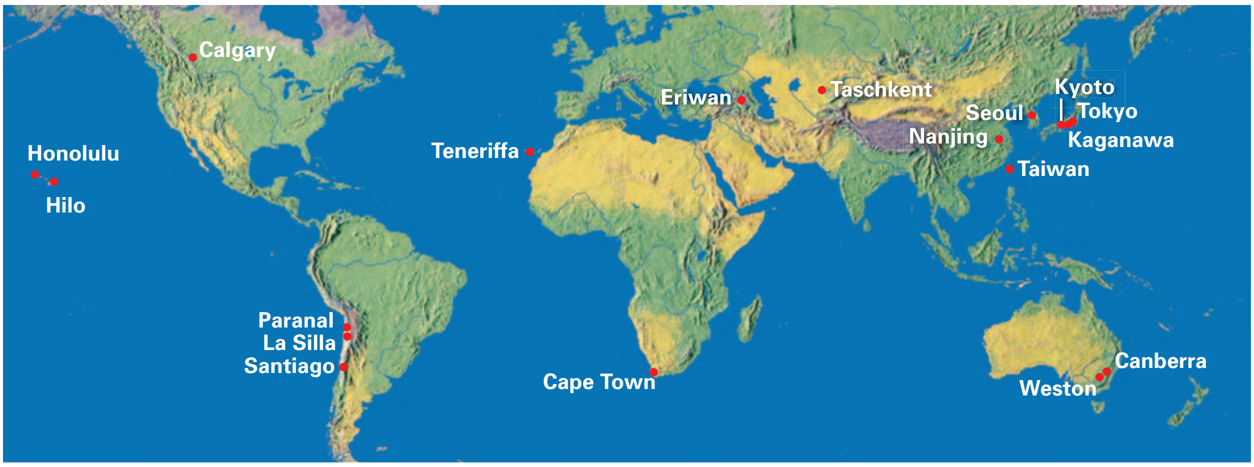
The MPIA is part of a DFG-funded research network ("Forschergruppe") on the first stages of planet formation. This network involves the University of Tübingen (chair), the MPIA (co-chair), the Institute for Geology and Geophysics in Heidelberg (co-chair), the Kirchhoff Institute for Physics in Heidelberg, the Institute for Theoretical Astrophysics in Heidelberg, the Institute for Planetology in Münster and the Institute for Geophysics and Extraterrestrial Physics in Braunschweig. It combines laboratory astrophysics with theoretical astrophysics and astronomical observations in order to gain a better understanding of how the first planetary embryos are formed out of the circumstellar dust surrounding a young star. The network funds 10 PhD students, most of which started in early 2007.

SISCO (Spectroscopic and Imaging Surveys for Cosmology): This EU network is dedicated to the study of galaxy evolution with the help of sky surveys. The Institute has made pivotal contributions to this network through CADIS, COMBO-17, and the GEMS surveys. Additional partners are: University of Durham, Institute for Astronomy in Edinburgh, University of Oxford, University of Groningen, Osservatorio Astronomico Capodimonte in Naples, and ESO in Garching.

Elixir, an EU network dedicated to exploit the unprecedented capabilities of the NIRSPEC instrument on the JWST space mission.

SDSS, the Sloan Digital Sky Survey, has revolutionized wide-field surveying at optical wavelengths. It is the most extensive imaging and spectroscopy sky survey to date, imaging about a quarter of the entire sky in five filters. The final catalogue will provide positions, magnitudes, and colors of an estimated one hundred million celestial objects as well as redshifts of about one million galaxies and quasars. The observations are made with a 2.5 m telescope specially built for this purpose at Apache Point Observatory, New Mexico. The project is conducted by an international consortium of US, Japanese and German institutes. The MPIA was the first of what is now twelve European partner institutes in SDSS and the only one to participate since the inception of surveying. In exchange for material and financial contributions to the SDSS, a team of scientists at the MPIA receives full access to the data. In 2005, the "original" SDSS was





Credit: (beide Bilder) NASA "Blue Marble" completed, but an extension, SDSS-II/Segue, focusing on Milky Way structure, was completed in mid 2008.

MPIA is a partner in Pan-Starrs1 (PS1), the most ambitious sky survey project since the SDSS, as part of the Pan-Starrs1 Science Consortium (PS1SC), using a dedicated 1.8 m telescope and the record-breaking 1.4-Gigapixel Camera (GPC1) with a 7-square-degree field of view. PS1SC is an international collaboration, involving the University of Hawaii, the MPE, Johns Hopkins University, the Harvard-Smithsonian Center for Astrophysics/Las Cumbres Observatory Global Telescope, the Universities of Durham, Edinburgh and Belfast, and Taiwan's National Central University. It will operate the PS1 telescope during 2009 – 2012 to carry out multiple time-domain imaging surveys in its g, r, i, z, y filter set: the "3 pi" survey of all of the sky visible from its location on Haleakala (Hawaii), a medium-deep supernova survey, as well as a dedicated survey of the Andromeda galaxy and a search for transiting planets. Including this planet search, MPIA scientists are leading four out of twelve key science projects within PS1SC, covering in addition the search for the most distant quasars and the coolest stars, as well as a comprehensive study of the Local Group's structure.

Within the Herschel Space Observatory project, MPIA is the largest Co-I instute in the Pacs instrument consortium, which consists of partners from 6 European countries. Herschel was successfully launched on May 14th , 2009. The institute leads two Herschelguaranteed Time Key Programs on "The earliest phases of star formation" and "The Dusty Young Universe: Photometry and Spectroscopy of Quasars at $z < 2$" and participates in nine other Herschel Open and Guaranteed Time Key Programs. All these observing programs are large international collaborations.

I.4 Educational and Public Outreach. The new "Haus der Astronomie"

Training the next generation of scientists and communicating astronomy to the public has a longstandig tradition on the Königstuhl. The "Haus der Astronomie", a new center for education and public outreach, whose establishment had been decided in December 2008, is presently being erected on the Campus of the MPIA. The new institution will amplify and strengthen the efforts of all Heidelberg astronomers directed to this goal.

Students come from all over the world to the MPIA to carry out research for their diploma or doctoral thesis. A majority of these students are formally enrolled at the University of Heidelberg. In turn, a number of scientists at the MPIA have adjunct faculty status at the University.

Undergraduate students can get a first taste of scientific work at the MPIA. The Institute offers advanced practical courses or enables the students to participate in "mini research projects". These last about two months and cover a wide range of questions, including the analysis of observational data or numerical simulations, as well as work on instrumentation. These practical courses offer the students an early, practically oriented insight into astrophysical research and is an eccellent preparatory step for a later diploma or doctoral thesis.

The International Max Planck Research School (IMPRS) for Astronomy and Cosmic Physics, which was established by the Max Planck Society and the University of Heidelberg, started in 2005, and offers PhD students from all over the world a three-years education under excellent conditions in experimental and theoretical research in the field of astronomy and cosmic physics. It is supported by the five astronomical research institutes in Heidelberg.

The institute's mission also includes educating and informing the general public about astronomical research. Members of the institute give talks at schools, education centers and planetaria. They also appear at press conferences or on radio and television programs, in particular on the occasion of astronomical events that attract major public attention. Numerous groups of visitors come to the MPIA on the Königstuhl and the Calar Alto Observatory.

Our initiative for the general public, a series of eight "Public Lectures on Sunday Morning", which was in its

Fig. I.11: The basic structure of the HdA was finished in Fall 2010.

Credit: MPIA

fifth year in 2010, always leads to a sold-out auditorium at the MPIA. Also, as in previous years, the one week long practical course which was offered to interested schoolchildren (BOGy), was immediately booked out – applicants came from all-over the country. And again, the MPIA participated in the Girls' Day, an annual nationwide campaign intended to encourage schoolgirls to learn about professions that are still mainly male-dominated. At various stations throughout the MPIA, about 40 schoolgirls got a general idea of the work at an astronomical institute.

In 2010, there were a lot of other activities and events. A more detailed description can be found in chapter V.

Finally, the monthly magazine "Sterne und Weltraum" (Stars and Space, SuW of the Spektrum-Verlag) is published at the MPIA. This journal is intended for the general public and offers a lively forum both for professional astronomers and for the large community of amateurs in the field. A significant fraction of our readers are teachers and pupils. In parallel to SuW, didactic material is produced monthly within our successful project "Science to schools!", which helps teachers to treat interesting themes of current astronomical research during regular classes in physics and natural sciences. The project "Science to schools!" was sponsored by the Klaus Tschira Foundation from 2005 to 2009, and is now continued in the "Haus der Astronomie". The didactic material is made freely available through the web and is widely used in german-speaking countries.

The "Haus der Astronomie" – a Center for Education and Public Outreach

The "Haus der Astronomie", which was founded in December 2008, is presently being erected on the campus of the MPIA. In this facility, the educational and public outreach activities of all astronomers in Heidelberg will be concentrated and developed further. Information for the media and the general public, the development of didactic material, simulations and visualizations, and the training of university students and teachers of physics, astronomy and natural sciences will play a major role. Furthermore, the HdA will support contacts and communication between scientists. The Klaus Tschira Foundation is financing the building and its technical equipment, and the Max Planck Society is operating the facility. In addition to these Institutions, the City of Heidelberg, the State of Baden-Württemberg, the University of Heidelberg are contributing to the personnel costs, and the astronomers at the MPIA and at the University's Center for Astronomy will also bring in activities related to public and educational outreach. During 2009, the center's core team was assembled, and construction work was started on October with a festive groundbreaking ceremony. At the end of 2010, the basic structure of the building, including the planetarium dome was finished. This was celebrated in a topping-off ceremony on December 17 (see chapter V for more details about the HdA).

II. Highlights

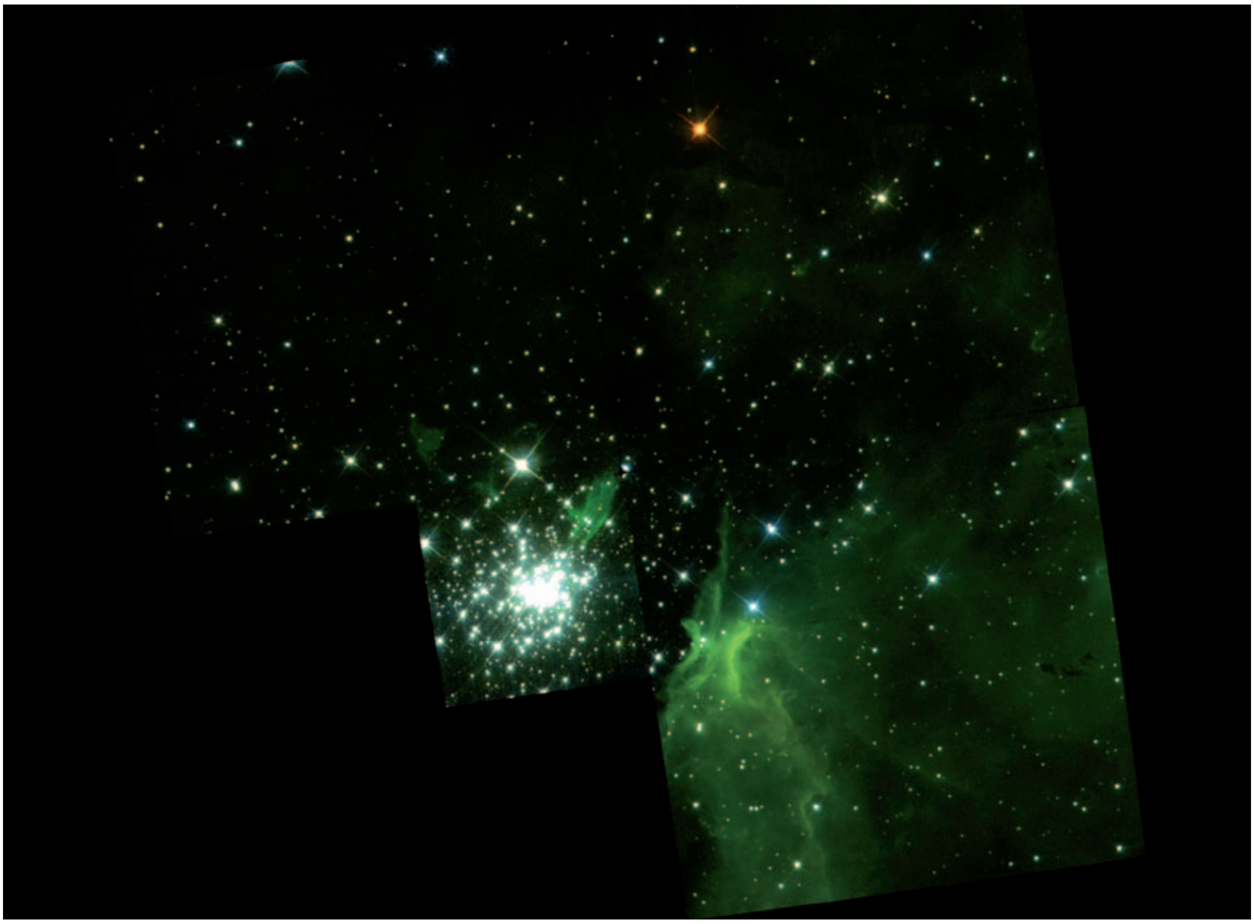
II.1 Stars in Motion

High precision study of star movement shows surprising unrest in massive star cluster

Using the Nasa / Esa Hubble Space Telescope, astronomers from the MPIA and the University of Cologne have completed a longterm study of one of the most massive young star clusters in the Milky Way, comparing two observations that were made ten years apart. The comparison, which relies on extremely precise measurements, reveals the motions of several hundreds of stars, which prove to be still far from equipartition of their kinetic energy: the cluster, born only one million years ago, is so young, that stellar motion had not enough time to "settle down", i.e. to distribute the total kinetic energy statistically among all stars within the cluster.

Ordinary star clusters ("open stellar clusters" or "stellar associations") disperse over time, as the different stars go their own separate ways. In very massive and compact clusters strong gravitational forces between all members lead to a different fate. In the long term, they evolve into those massive aggregations of stars known as "globular clusters", whose tightly packed stars remain gravitationally bound to each other for billions of years. With a mass of more than 10 000 suns packed into a volume with a diameter of a mere 3 lightyears, the massive young cluster in the giant nebula NGC 3603 is one of the most compact stellar clusters in the Milky Way. For comparison: in our own immediate stellar neighborhood, the same volume contains no more than a single star, namely the Sun. NGC 3603 is located in the central plane of our home galaxy's main disk, in a region called the Carina

Fig. II.1.1: Partial view of the giant galactic nebula NGC 3603 with its central, one million years old compact starburst cluster. This false-color image is based on observations with the Wide Field/Planetary Camera 2 of the Hubble Space Telescope. The dominant green color signalizes light emitted as ionized hydrogen regains its missing electron ("recombination line H-alpha"). The field of view is about 160 arc seconds on each side. The image shape is due to the detector placement of the Wide Field/Planetary Camera 2.



Credit: Nasa / Esa / MPIA / University of Cologne spiral arm, at a distance of more than 20 000 lightyears from the Sun (see Fig. II.1.1). The nebula is excited by the radiation of numerous hot and massive members of the star cluster, which were formed very recently in a single "burst of star formation." Could this young object be a globular cluster in the making?

To find out, a team of astronomers led by Wolfgang Brandner (MPIA) tracked the individual movement of the cluster's many stars. Such a study can reveal whether the stars were in the process of drifting apart, or about to settle down. It also serves to distinguish members of the star cluster from unrelated stars that, as viewed from Earth, just happen to fall along the same line of sight.

Measurements at the limit

Measurements of this kind are notoriously difficult. Imagine a star moving sideways at a rate of a few kilometers per second – a typical speed within stellar clusters. Viewed from a distance of 20 000 lightyears (the actual distance of NGC 3603 from Earth), such a star's position on the night sky would shift by no more than a few billionths of an angular degree per year, at the limit of the capability of today's most precise observations.

By using two observations, made ten years apart with the same camera aboard the Hubble Space Telescope, and by performing an intricate analysis to account for all possible disturbances, Brandner and his colleagues were able to reach the required accuracy.

All in all, the team observed more than 800 stars. About 50 of these were identified as foreground stars, which are unrelated to the cluster. From the remaining sample of more than 700, the astronomers were able to obtain sufficiently precise speed measurements for 234 cluster stars of different masses and surface temperatures. However, for stars with either particularly high or particularly low masses, the position could not be fixed with the required accuracy. For very bright and massive stars, parts of the detector are saturated, making it very hard to find the center of the little disk as which the star appears on the image. Stars with very low masses are comparatively faint; those stars are not sufficiently clearly distinguishable from the background ("low signal to noise ratio") for position measurements of the required precision.

Boyke Rochau (MPIA), the paper's lead author, who performed the data analysis as part of his PhD work, explains: "*Once our analysis was completed, we reached a precision of 27 millionths of an arc second per year. Imagine you are in Bremen, observing an object that is located in Vienna, that is about 800 kilometers or 500 miles away. Now the object moves sideways by the breadth of a human hair. That's a change in apparent position of about 27 millionths of an arc second.*"

A surprising result

The results for the motion of these cluster stars were surprising: According to widely accepted models, which reproduce what is actually observed in older globular clusters, the average stellar speed in a cluster like the one in NGC 3603 should depend on mass: Stars with lower mass should move faster, and those with higher mass should move more slowly. More precisely, all these stars should have, on average, the same kinetic energy. Kinetic energy is proportional to an object's mass and to the square of its velocity. By this count, stars with one half the mass of the Sun should, on average, move four times faster than stars with one solar mass. But in the NGC 3603 cluster, the stars for which precision measurements were possible represent a range of masses between 2 and 9 times that of the Sun. Yet all of them move at about the same average speed of 4.5 km/s (corresponding to a change in apparent position of a mere 140 microarc seconds per year). Average speed does not appear to vary with mass at all.

This means, that apparently – and surprisingly – this very massive star cluster has not yet settled down. Instead, the stars' velocities still reflect conditions from the time the cluster was formed, approximately one million years ago: for the first time, astronomers have been able to measure precise stellar motions in a compact star cluster in such an early stage of evolution. This is key information for astronomers trying to understand how such starburst clusters are formed, and how they evolve.

Vexingly, the question of whether or not the massive young cluster in NGC 3603 will become a globular cluster remains open. Given the new results, it all depends on the speeds of the numerous lowmass stars, which were too faint to allow for precise speed measurements with the Hubble Space Telescope. To find out whether or not the star cluster will disperse, it will be necessary to wait for the next generation of telescopes, such as the James Webb Space Telescope (JWST) or ESO's European Extremely Large Telescope (E-ELT).

Boyke Rochau, Wolfgang Brandner,
Mario Gennaro, Nicola Da Rio,
Natalia Dyurkevich, Thomas Henning (MPIA),
Andrea Stolte (University of Cologne)

II.2 A New Astronomical Phenomenon

Coreshine provides insight into stellar births

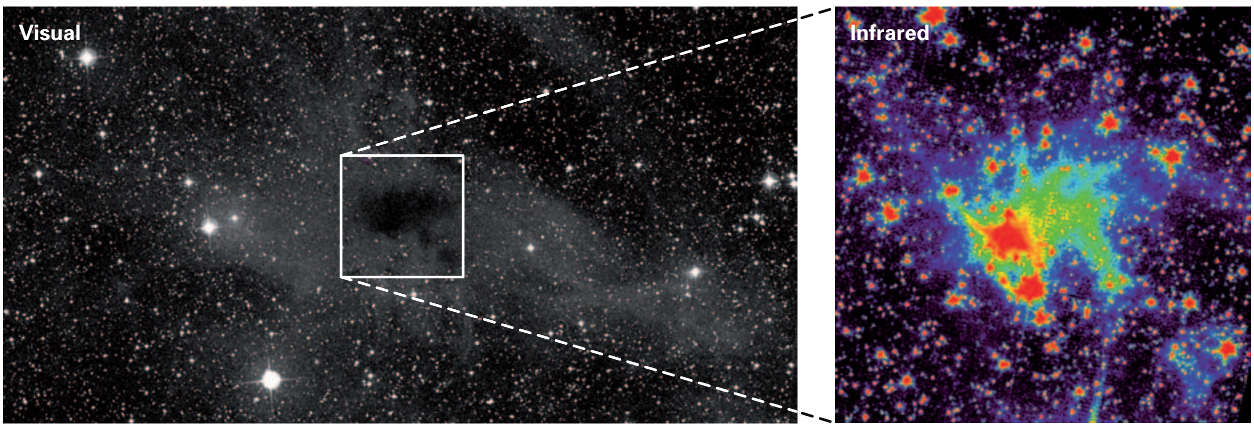
Astronomy is literally in the dark when it comes to the birth of stars, which occurs deep inside clouds of gas and dust: These clouds are completely opaque to ordinary light. Now, a group of scientists has discovered a new astronomical phenomenon that appears to be common in such clouds, and provides a new window onto the earliest phases of star formation. The phenomenon – light that is scattered by unexpectedly large grains of dust, which the discoverers have termed "coreshine" – probes the dense cores where stars are born.

Stars are formed as the dense core regions of cosmic clouds of gas and dust ("molecular clouds") collapse under their own gravity. As a result, matter in these regions becomes ever denser and hotter until, finally, nuclear fusion is ignited: a star is born. This is how our own star, the Sun, came into being; the fusion processes are responsible for the Sun's light, on which life on Earth depends. The dust grains contained in the collapsing clouds are the raw material out of which an interesting byproduct of star formation is made: solar systems and Earthlike planets.

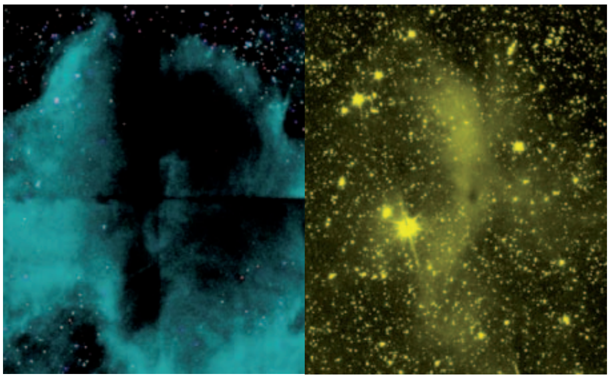
What happens during the earliest phases of this collapse is largely unknown, but now this situation may change. Recently, an international team of astronomers, led by Jürgen Steinacker (MPIA) and Laurent Pagani (LERMA Observatoire de Paris), discovered a new phenomenon which promises information about the crucial earliest phase of the formation of stars and planets: "coreshine", the scattering of mid-infrared light (which is ubiquitous in our galaxy) by dust grains inside such dense clouds. This scattered light carries information about the size and spatial density of the dust particles, about the age of the core region, the spatial distribution of the gas, the prehistory of the material that will end up in planets, and about chemical processes in the interior of the cloud.

Until now, mid-infrared light was thought to carry hardly any information about molecular clouds: The clouds themselves are too cold for their thermal radiation to feature in this wavelength range, and most clouds do not contain nearly enough matter to absorb significant amounts of the mid-infrared radiation flooding our galaxy (the galactic background radiation). That's why, when in 2009 Steinacker and his colleagues noticed mid-infrared radiation in observations of the molecular cloud L 183 which had been made using NASA's SPITZER Space Telescope, they faced a puzzle: Complex simulations of how radiation and matter interact within such a cloud showed that this was scattered light – portions of the galactic mid-infrared background radiation that had been absorbed by cloud matter, and reemitted in all directions. But it was physically impossible for the presumed content of the cloud – with dust grains of up to 0.1 micrometer in diameter – to scatter radiation at these wavelengths. In order to account for their observations, the researchers had to include dust particles that were ten times larger. This amounted to the discovery of a new phenomenon: the scattering of mid-infrared radiation by larger dust particles in the cores of molecular clouds.

Fig. II.2.1: The molecular cloud CB 244 in the constellation Cepheus, 650 light-years from Earth. In such clouds, the Milky Way's light is scattered in different ways: Visible light is predominantly scattered by small grains of dust in the cloud's outer regions ("cloudshine"), while the densest central parts of the nebula are really "dark". The false-color image shows mid-infrared light scattered by larger grains of dust in the interior of the cloud, the newly discovered "coreshine".



Credit: MPIA

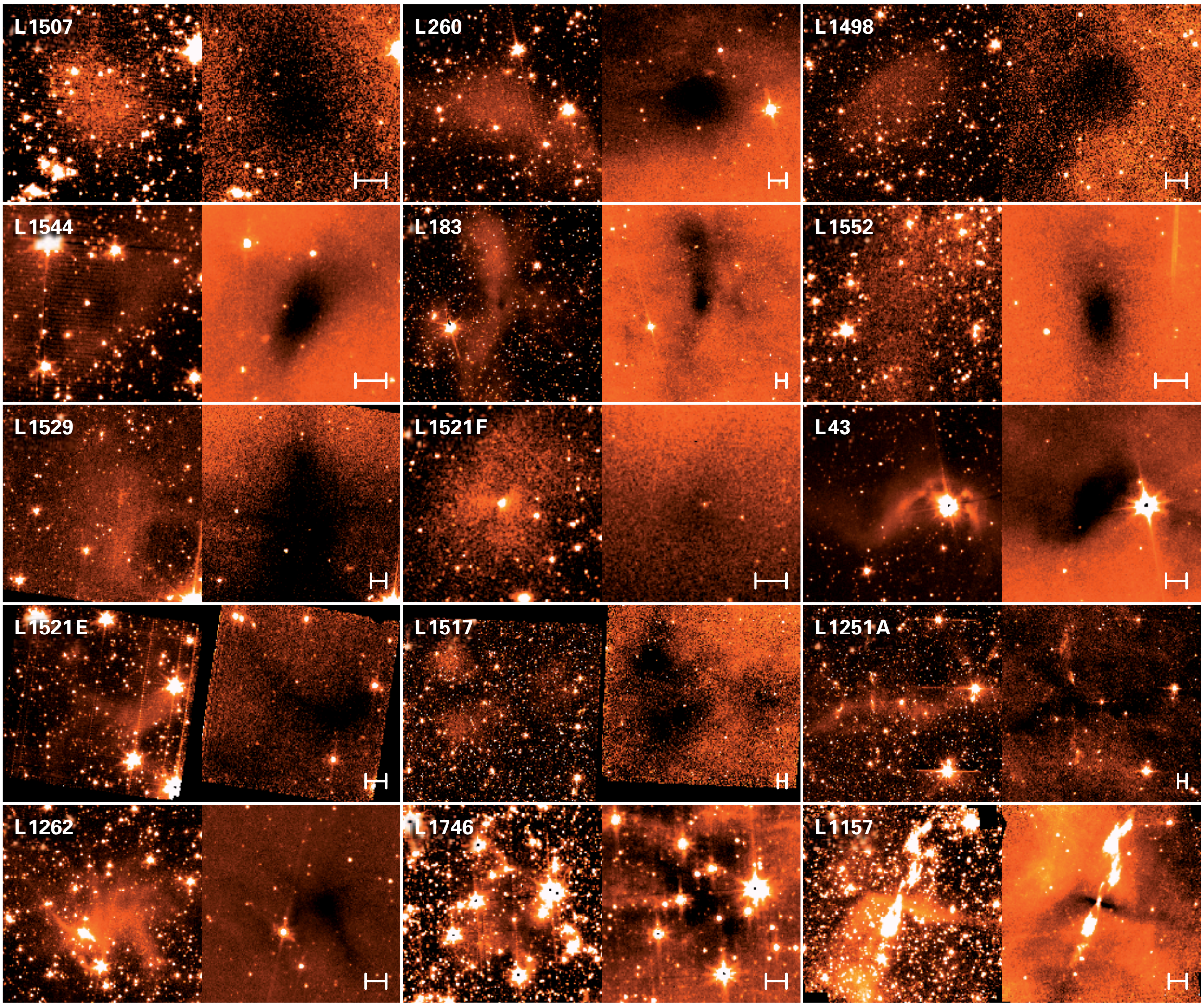


Credit: J. Steinacker et al., MPIA

Fig. II.2.2: The left image of the molecular cloud L 183 (*shown in blue, false-color*) was taken with the Canada France Hawaii Telescope in near-infrared light (wavelength: 0.9 micrometers). Here there is „cloudshine“: light scattered by smaller dust grains in the cloud's outer regions. The right image (*yellow, false-color*) was taken with the Spitzer Space Telescope in the mid-infrared (wavelength: 3.6 micrometers) and shows the newly discovered “coreshine”: light scattered by larger grains of dust in the cloud's denser core regions.

An unexpected mid-infrared radiation

As published in February 2010, Steinacker, Pagani and colleagues from Grenoble and Pasadena detected unexpected mid-infrared radiation from the molecular cloud L 183 in the constellation Serpens Cauda (“Head of the snake”), at a distance of 360 light-years. The radiation appeared to originate in the cloud's dense core (Fig. II.2.2). Comparing their measurements with detailed simulations, the astronomers were able to show that they were dealing with light scattered by dust particles with diameters of around one micrometer (one millionth of a meter), which is larger than expected by a factor of ten.



Credit: Irac / Spitzer

Fig. II.2.3: Coreshine can be observed at a variety of stages of star formation within dense molecular clouds. In this picture gallery, 15 examples are shown. In each case, the molecular cloud core is shining bright on the left image, taken at 3.6 mm wavelenght, while on the right image, taken at 8.0 microns, the dense core appears dark again, since the dust in the core absorbs the background radiation. The white bar in the bottom right corner of the 8-micron images represents a length of 4000 astronomical units or about 22 light days.

The follow-up research that was later published in Science clinched the case: The researchers examined 110 molecular clouds at distances between 300 and 1300 light-years, which had been observed with Spitzer in the course of several survey programs. The analysis showed that the L 183 radiation was more than a fluke. Instead, it revealed that coreshine is a widespread astronomical phenomenon: roughly half of the cloud cores exhibited coreshine, mid-infrared radiation associated with scattering from dust grains in their densest regions. Some of the most prominent examples of sources with coreshine are displayed in Fig. II.2.3. The dust in the core absorbs the background radiation at 8 micron wavelenght (right-hand image for each core) while it also scatters the external radiation field at 3.6 microns (lefthand image for each core). The good spatial correlation of the scattered light flux at 3.6 microns with the extinction at 8.0 microns shows that the coreshine is light scattered from the densest parts of the molecular cloud cores.

Coreshine – a new tool for exploring dense cores

Coreshine is observed in a variety of dark clouds in very different stages of prestellar evolution and star formation. In L 1157, for instance, the last object shown in the gallery (*bottom right*), we look at an accretion disk in which a young star is embedded. The disk appears as a dark horizontal bar at 8.0 microns (*right image*), while it is shining brightly at 3.6 microns. Accretion of gas and dust falling from the disk onto he central star drives a bright gaseous outflow (a bipolar jet), which is streaming away from the disk at high velocity in both polar directions.

The discovery of coreshine suggests a host of follow-on projects – for the Spitzer Space Telescope as well as for the James Webb Space Telescope, which is due to be launched in 2018. The first coreshine observations have yielded promising results: The unexpected presence of larger grains of dust (diameters of around a millionth of a meter) shows that these grains begin their growth even before cloud collapse commences. An observation of particular interest concerns clouds in the Southern constellation Vela, in which no coreshine is present. It is known that this region was disturbed by several stellar (supernova) explosions. Steinacker and his colleagues hypothesize that these explosions have destroyed whenever larger dust grains had been present in this region.

In summary, coreshine opens a new window into the dense cores of molecular clouds – and promises a rich harvest of information about the earliest phases of star formation. The growth of dust particles inside clouds can be used to make deductions about density fluctuations and turbulence inside the cloud. The mechanism behind coreshine – the scattering of light – is highly sensitive to changes in the density of cloud matter. In this way, coreshine can be used to infer the three-dimensional density distribution of the gas. In addition, the growth of dust particles is a continuous process. This allows for an estimate of the denser region's (the "cloud core's") age. The dust particles play a key role when it comes to cloud chemistry – chemical reactions taking place on their surfaces are an important factor in the evolution of the cloud's chemical composition. This is where coreshine and more traditional observations that provide information about the abundances of different species of molecules in the cloud (infrared, submm, radio), complement each other.

Jürgen Steinacker, Amelia Stutz,
Thomas Henning (MPIA),
Laurent Pagani (Lerm, Observatoire de Paris),
Aurore Bacmann (Université de Grenoble)

II.3 Snow Banks in Proto-planetary Disks

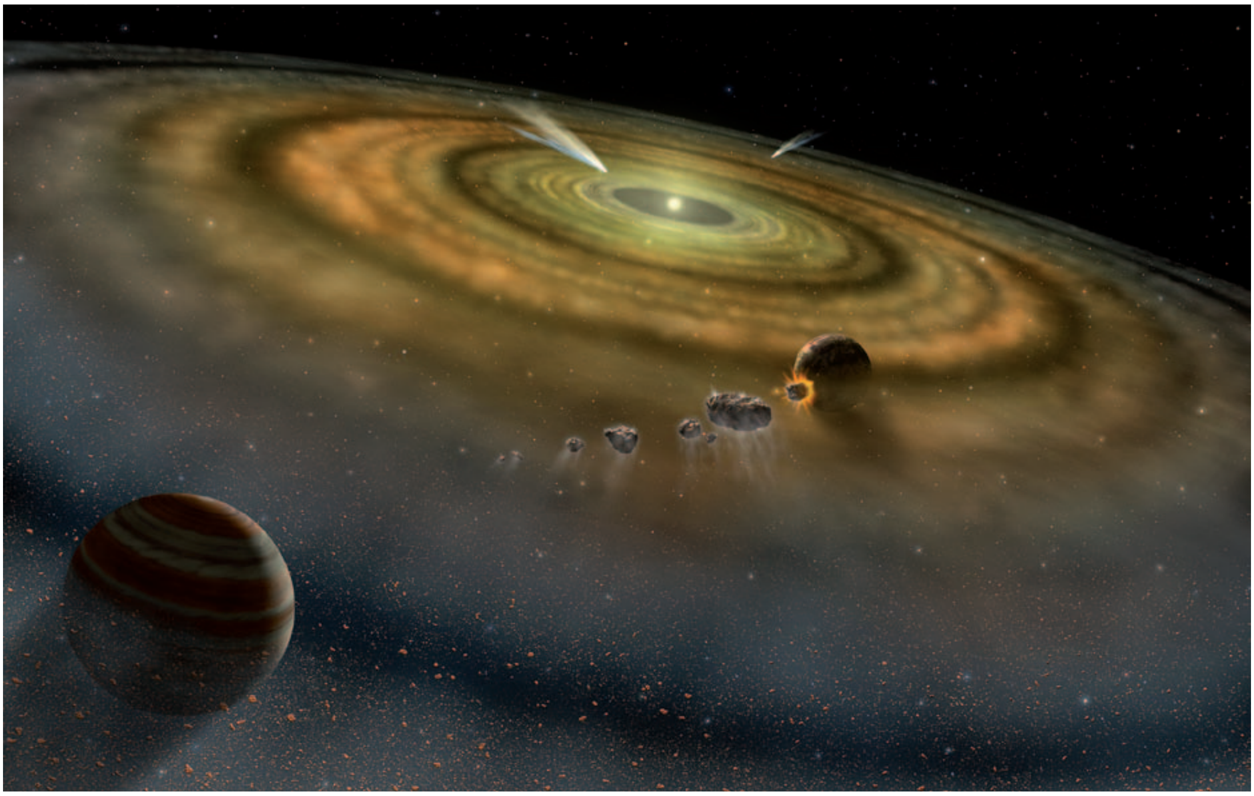
Another step towards understanding the growth of protoplanets

So far observers have little clues what really happens in circumstellar disks during the process of growing dust grains into planets. They have good indication that grains are significantly larger than in the interstellar medium, which means millimeters instead of micrometers. Anything larger than millimeters cannot be detected for physical and technical reasons. Eventually the disks are gone and planets can be found around most stars. What has happened in between?

This is the playground for the theorists in MPIA's Planets and Star Formation department. Current theories tell us that the grains continued to grow, became kilometer sized planetesimals and eventually planetary embryos which ultimately build the terrestrial planets or formed the cores of the gas giants. But the first steps in this growth scenario are already quite problematic, as we will see.

As nobody so far had a close look into such a dusty gas disk we have to invoke some similar situations from our not daily but at least winterly experiences on earth to explain the processes. Before it is snowing little ice crystals have to collide up in the clouds and form larger and larger snowflakes. The same happens in proto-planetary disks and also the material is basically identical – water ice is also a dominant species at distances larger than 4 Astronomical Units (1 AU is the distance from the Earth to the Sun) where Jupiter's core formed. And just as the snow flakes settle to the ground they also settle out of the solar nebula into the Sun, or at least close enough to the Sun to evaporate. Larger snow flakes sediment faster to the ground and likewise do larger agglomerates first move towards the mid plane of the solar nebula and then towards the Sun. Both the Earth's atmosphere and the solar nebula had to build up a pressure gradient pointing away from the central gravitating body – Earth or Sun – to stay in dynamical equilibrium. And because the snow and ice flakes do not feel a pressure gradient, as they are so much denser than the surrounding gas, they cannot be in dynamical equilibrium and climb virtually up the pressure gradient. In this picture thus also dust flakes in our

Fig. II.3.1: Our scientific view of extra-solar planets in their formation stage is not yet as detailed as this artist's view. But the interplay of observations and theoretical studies – mainly through detailed numerical modeling of all kinds of physical processes within the circum-stellar disk – improves our understanding of this fundamental phase of stellar evolution step by step.



Credit: NASA / Fuse / T. Cook

study room do move to the location of highest air pressure, which is at the ground. This is no surprise because the pressure gradient had to form because of gravity, which is of course the joint reason for the pressure structure and the settling of solids in an atmosphere.

If one now carefully estimates the growth time that the grains in the solar nebula need to grow into meter sized boulders one does notice that this time is longer than what the decimeter- sized pebble would need to literally fall into the Sun. Turbulence has now been invoked to shorten the growth time in fostering collisions and counteracting the sedimentation to the mid plane of the nebula, where it is not wrong to imagine a snow storm with its whirling snow flakes. Unfortunately, if one again looks carefully at the proper conditions in the solar nebula one recognizes that one only has replaced one evil with another. In order to speed up the collision rates between the ice flakes in the solar nebula sufficiently, turbulence has to be so strong that the actual collisions do not lead to sticking and growth any more – rather, they are so energetic that the flakes shatter into pieces. This is now the significant difference between the wet snowflakes at earth, always close to the melting point and the super cold and dry ice flakes in the solar nebula where the low gas pressure takes care that no liquid water can exist. The latter ones can much easier be destroyed, as their structure is closer to a crystal glass than a snowball.

So on a first glance turbulence does not help a lot, but this is still not the entire truth. Snowstorms do not only whirl up snow, they also can pile up huge amounts of snow into snow banks, typical at regions where the storm is hindered by some obstacles, like bushes or houses. Natalia Dzyurkevich and her colleagues were now able to show that quite the same can happen in the solar nebula. Here there are regions where the magnetic turbulence changes its strength because the local degree of ionization of the gas changes. Remember the storm in the disks is hydromagnetic turbulence that can only operate if there are enough free charges (mainly electrons) in the disk for the magnetic field to couple to the gas. If the number of free electrons is not sufficient magnetic field and gas decouples and the turbulence dies out. Colleagues from Santa Cruz had now speculated that at regions in the solar nebula where the ionization degree changes, for instance closer to the star it is warmer and thus less ice and more electrons are present, the turbulence also changes its strength or even seizes from one distance to the star to the next one. At these places the disk could form local pressure maxima which themselves would trap the radial rainout of ice and dust grains from the solar nebula.

Dzyurkevich was now the first person to perform a 3D global magneto-hydrodynamical simulation with a realistic variation of the ionization degree on our institute's Computer Cluster in Garching. She found that indeed at the interface between magnetic active and inactive regions the turbulence finds an obstacle to create not only a local pressure bump but also to trap and concentrate dust grains there, saving them from radial drift and building a reservoir for planetesimal formation. The actual planetesimal formation step is likely to look like an avalanche, e.g. when the dust and ice flake density exceeds the gas density and the self gravity of this ice and dust makes the concentration collapse under its own weight – but that is a whole different story (see previous Annual Reports).

Not only dust and ice pebbles are subject to this radial drift and have to be saved in these pressure maxima created at the interface between active and inactive turbulence. Also planetary embryos usually migrate faster in the solar nebula than is good for them. This radial migration is not mitigated by the gas pressure as for the small grains but by the tidal interaction between the embryos and the disk gas. The result is the same: planets would fall into the star before they reach Jupiter's mass. This is an obvious contradiction to reality that needs to be remedied. Here the previously invoked pressure bump can also help, because it is connected to a larger radial area in the disk where the disk has an unusual radial density and temperature structure. The simulation of Natalia Dzyurkevich showed here clearly that in her 3D global disk simulation also planetary embryos would have been stopped from radial migration, allowing them to eventually grow to fullsized planets.

Natalia Dzyurkevich, Mario Flock,
Neal J. Turner, Hubert Klahr
and Thomas Henning

II.4 An Exoplanet from Another Galaxy

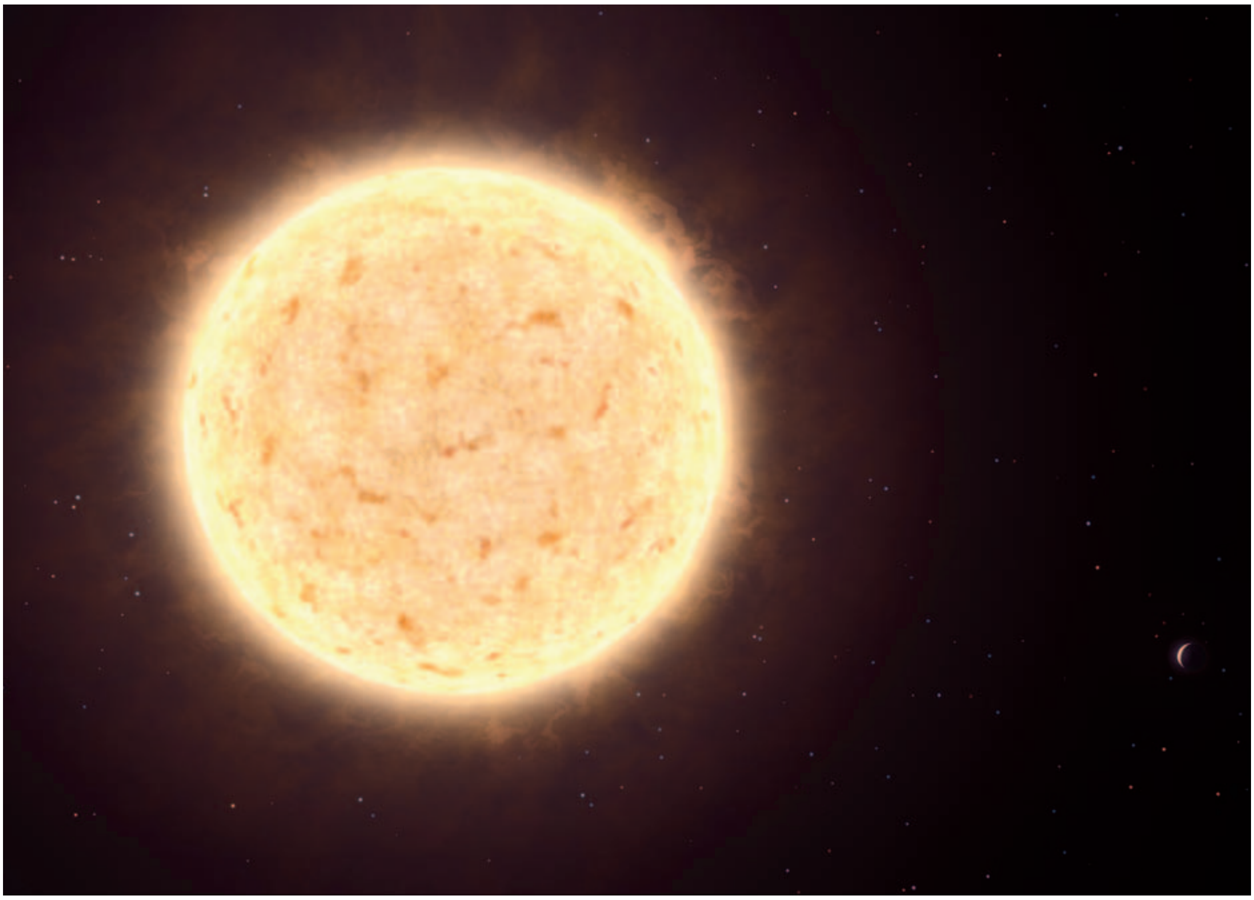
Good news for the distant future of the Solar System Astronomers have discovered the first exoplanet that originated in another galaxy. The planet's host star belongs to a dwarf galaxy which was swallowed up by our home galaxy, the Milky Way, billions of years ago. Remarkably, the Jupiter-like planet orbits a star nearing the end of its life. It appears to have survived the star's "Red giant" stage, which offers a tantalizing glimpse of one possible fate of our own Solar System in the distant future.

Over the last 15 years, astronomers have detected more than 700 exoplanets orbiting ordinary stars in our cosmic neighborhood. Now, for the first time, astronomers have detected an exoplanet whose origin appears to lie outside our own galaxy. The planet, which has been designated HIP 13044 b, has a minimum mass of 1.25 times the mass of Jupiter. The star system is located about 2000 light-years from Earth in the southern constellation Fornax ("the chemical furnace").

The planet was discovered with the radial velocity method, which measures tiny wobbles of a star caused by a planet's gravitational pull. HIP 13044's wobbles were detected with the high-resolution spectrograph FEROS at the 2.2 m MPG/ESO telescope at ESO's La Silla observatory in Chile.

The planet and its host star appear to have originated in a dwarf galaxy that was swallowed by the Milky Way galaxy between six and nine billion years ago. Such galactic cannibalism is an ordinary occurrence in galactic evolution. Typically, remnants of swallowed-up dwarf galaxies can be detected as ribbon-like arrangements of stars known as "stellar streams". In this case, HIP 13044 is part of the so-called "Helmi stream". Spiral galaxies like our own Milky Way grow by swallowing smaller galaxies, so-called "dwarf galaxies". During these acts of cannibalism, the dwarf galaxy is distorted severely. One typical outcome are "stellar streams", longish structures made of stars which wrap around the larger galaxy (see

Fig. II.4.1: An exoplanet from another galaxy (*right*) and its star (*left*): artist's impression of the yellowish star HIP 13044 and, on the bottom right, its planet HIP 13044 b. HIP 13044 is part of a stellar stream, a remnant of a dwarf galaxy that was swallowed by the Milky Way galaxy billions of years ago.



Credit: ESO/L. Calçada

Fig. II.4.2 and Chapter II.5 of this Annual Report). Over the course of a few billion years, these stellar streams grow ever more distinct as their stars mix with the larger galaxy's own. In the case of HIP 13044, the stellar stream is clearly detectable – it is the "Helmi stream", which is very well studied, and the star HIP 13044 clearly belongs to that stream. This means that HIP 13044 used to be part of the earlier dwarf galaxy and, going by age estimates based on models of stellar evolution, should definitely have been part of the dwarf galaxy before it was swallowed by the Milky Way. The same should hold for the planet HIP 13044 b, making it indeed an exoplanet born in another galaxy.

"This is an exciting discovery," says Rainer Klement of the MPIA, who was responsible for the selection of the target stars for this study. *"For the first time, astronomers have detected a planetary system in a stellar stream of extragalactic origin. Because of the great distances involved, there are no confirmed detections of planets in other galaxies. But this cosmic merger has brought an extragalactic planet within our reach."*

Exoplanet survived red giant stage

The newly discovered system has a number of unusual properties. *"We found HIP 13044 b as part of a systematic search for exoplanets around stars that are nearing the end of their life,"* says MPIA's Johny Setiawan, who led the research. While the host star HIP 13044 was probably rather similar to our own Sun earlier on, it has since gone through the "Red Giant" phase, in which a star cools and expands to hundreds of times the radius of the Sun. It has now settled down into another quiet phase powered by the nuclear fusion of Helium, which is expected to last a few million years in total.

The fact that the exoplanet survived the red giant stage provides an intriguing glimpse of one possible fate of our own planetary system: our Sun is expected to become a red giant in around five billion years. Setiawan and his colleagues hypothesize that HIP 13044 b's current close orbit – its present average distance to its host star amounts to a mere 12 per cent of the distance between the Sun and the Earth, with an orbital period of only 16.2 days – was initially much larger, and that the planet migrated inwards during the star's Red Giant phase.

There is some evidence that some closer-in planets did likewise, and did not survive: *"HIP 13044 is rotating relatively quickly for a star of this particular type,"* says Setiawan. *"One possible explanation is that HIP 13044 swallowed its inner planets during the Red Giant phase, which would make the star spin more quickly."* HIP 13044 b's survival might be in jeopardy, though. In the next stage of its evolution, the star is headed for renewed expansion, and may engulf the planet.

With only this single case observed, it is impossible to tell how common this particular evolution is. More definite conclusions – and an understanding of how much HIP 13044 tells us about our own planetary system's future – will only be possible once significantly more planets orbiting similar stars – stars that have reached the later stages of stellar evolution – have been found. This is the aim of an ongoing search by Setiawan and his colleagues.

Fig. II.4.2: Smaller satellite galaxies caught by a spiral galaxy are distorted into elongated structures consisting of stars, which are known as tidal streams, as shown in this artist's impression.

Credit: Jon Lomberg

One final puzzle is that the new planet's host star HIP 13044 appears to contain very few elements heavier than hydrogen and helium – fewer than any other star with planets (in technical terms, it is "extremely metal-poor" – in astronomical parlance, all elements heavier than hydrogen and helium are called "metals"). *"It is a puzzle for the widely accepted model of planet formation how such a star, which contains hardly any heavy elements at all, could have formed a planet,"* adds Setiawan. HIP 13044 is extremely poor in metals – it contains less than 1 percent as many metals as the Sun. In the most widely accepted model of planet formation ("core accretion"), this is very unusual. The prediction of these models is: The higher the metal abundance in the system, the higher the probability to form a planet. This is evidence for alternative mechanisms of planet formation (e.g. those involving "gravitational instabilities"), which allow for the formation of planets irrespective of the the metal content of their central star and circumstellar matter.

Johny Setiawan, Rainer J. Klement, Thomas Henning, Hans-Walter Rix, Boyke Rochau, Tim Schulze-Hartung (MPIA), Jens Rodmann (ESTEC)

II.5 Spirals Eat Dwarfs

Galactic tendrils shed light on evolution of spiral galaxies

Spiral galaxies grow by swallowing smaller dwarf galaxies. As the dwarf galaxies are digested, they are severely distorted, forming structures such as surreal tendrils and stellar streams that surround their captors. Now, for the first time, a new survey has detected such telltale structures in galaxies more distant than our immediate galactic neighbourhood. This opens up the possibility of testing our current views of galaxy evolution in a new way.

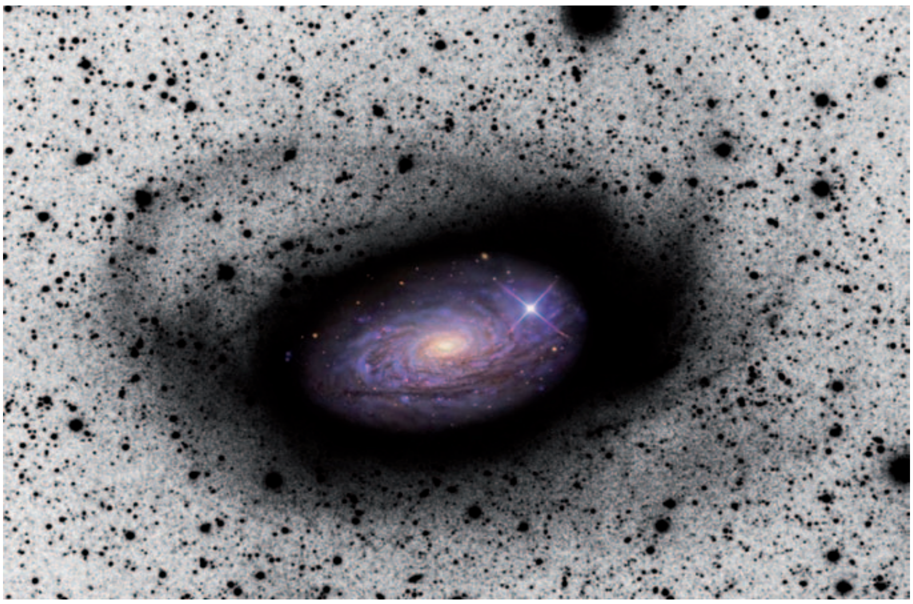
Around the Milky Way galaxy and in the vicinity of our immediate cosmic neighborhood, known as the "Local Group" of galaxies, traces of spiral galaxies swallowing dwarf galaxies have been known since 1997. But the Local Group with its three spiral galaxies and numerous dwarfs is a much too small sample to see whether theoretical predictions of the frequency of such digestive processes match observations. Now, for the first time, a new survey has managed to detect the telltale tendrils of galactic digestion beyond the Local Group. An international group of researchers led by David Martínez-Delgado (MPIA and Instituto de Astrofísica de Canarias) has completed a pilot survey of spiral galaxies at distances of up to 50 million light-years from Earth, discovering the tell-tale signs of spirals eating dwarfs.

When a spiral galaxy is approached by a much smaller companion, such as a dwarf galaxy, the larger galaxy's uneven gravitational pull severely distorts the smaller star system. Over the course of a few billions of years, tendril-like structures develop that can be detected by sensitive observation. In one typical outcome, the smaller galaxy is transformed into an elongated "tidal stream" consisting of stars that, over the course of additional billions of years, will join the galaxy's regular stellar inventory through a process of complete assimilation. The study shows that major tidal streams with masses between 1 and 5 percent of the galaxy's total mass are quite common in spiral galaxies.

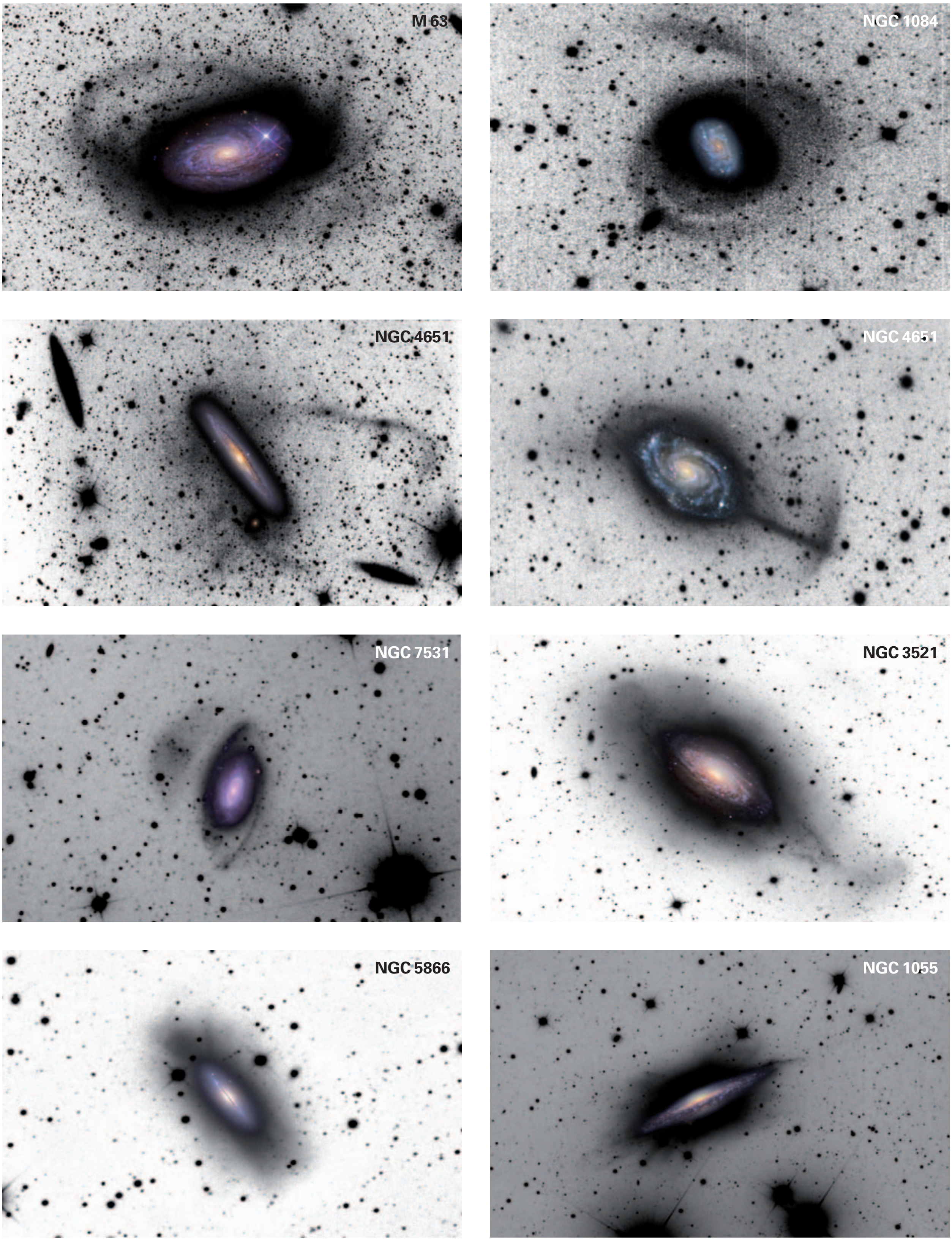
Simulations predicted observations

Detailed simulations depicting the evolution of galaxies predict both tidal streams and a number of other distinct features that indicate mergers, such as giant debris clouds or jet-like features emerging from galactic discs. Interestingly, all these various features are indeed seen in

Fig. II.5.1: Stellar streams around the galaxy M 63: remnants of a satellite dwarf galaxy that M 63 has swallowed. The central part is an ordinary positive image; in the outer regions, the negative of the image is shown. In this way, the faint structures that are the target of this survey are more readily discerned. This galaxy's distance from Earth is around 30 million light-years. The new survey has, for the first time, shown the presence of such tell-tale traces of spiral galaxies swallowing smaller satellites for galaxies more distant than our own "Local Group" of galaxies.



Credit: R. Jay Gabany (Blackbird Obs.) in collaboration with D. Martínez-Delgado (MPIA and IAC) et al.



Credit: D. Martínez-Delgado (MPIA and IAC), R. Jay Gabany (Blackbird Observatory), K. Crawford (Rancho del Sol Observatory) et al.

Fig. II.5.2: Examples for traces of spirals swallowing dwarf galaxies, as found with the new survey. For all images, the central part is an ordinary positive image. In the outer regions, the negative of the image is shown. Wisps, plumes, stellar streams, partially disrupted satellites or stellar cloud indicate that we are witnessing merger processes. *Left column from top to bottom: M 63, NGC 4651, NGC 7531, NGC 5866. Right column from top to bottom: NGC 1084, NGC 4651, NGC 3521, NGC 1055.*


Credit: Gabany / Martínez-Delgado

Fig. II.5.3: One of the galaxies in the survey, NGC 4651 shows a remarkable umbrella-like structure. It is composed of tidal star streams, the remnants of a smaller satellite galaxy which NGC 4651 has attracted and torn apart. This galaxy's distance from Earth is 35 million light-years.

the new observations – impressive evidence that current models of galaxy evolution are indeed on the right track.

The ultradeep images obtained by Delgado and his colleagues open the door to a new round of systematic galactic interaction studies. Next, with a more complete survey that is currently in progress, the researchers intend to subject the current models to more quantitative tests, checking whether current simulations make the correct predictions for the relative frequency of the different morphological features.

Remarkably, these cutting-edge results were obtained with the telescopes of ambitious amateur astronomers: For their observations, the researchers used telescopes with apertures between 10 and 50 cm, equipped with commercially available CCD cameras. The telescopes are robotic (that is, they can be controlled remotely), and are located at two private observatories in the US and one in Australia. The results attest to the power of systematic work that is possible even with smaller instruments: While larger telescopes have the undeniable edge in detecting very distant, but comparatively bright star systems such as active galaxies, this survey provides some of the deepest insight yet when it comes to detecting ordinary galaxies that are similar to our own cosmic home, the Milky Way.

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Stefano Zibetti, Hans-Walter Rix
in collaboration with colleagues from
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Rancho del Sol Observatory (Modesto, CA),
University of Virginia, Observatoire de Paris,
Massachussetts Institute of Technology,
Institute of Astronomy (Cambridge, UK),
University of Texas at Austin,
Argelander Institut für Astronomie (Bonn)

II.6 Molecular Gas in the Wirlpool Galaxy

Giant molecular clouds (GMC) provide the raw material out of which stars are formed in spiral and irregular galaxies. While in the past they have been studied in great detail in our own Galaxy and in its nearest neighbours, the members of the Local group, low resolution studies of more distant spiral galaxies seemed to indicate that the physical properties of their GMCs were quite different. The high-resolution interferometric observations presented here show, that this is essentially not the case.

Detailed interferometric studies of the GMCs in the Milky Way Galaxy and in other members of the Local Group have shown that their properties are remarkably similar over a large range of environments. Outside the Local Group, most studies of spiral galaxies were undertaken using single-dish observations, by which the GMCs cannot be spatially resolved. Thus, it is not obvious, that the results derived from interferometric studies within the Local Group are valid also for these more distant galaxies. Detailed analysis of the molecular gas at about the scale of GMCs has been performed only for the central regions of a few nearby irregular galaxies like M 82 – such studies suggest that the properties of the GMCs in these objects differ from those found in nearby galaxy disks by exhibiting higher kinetic temperatures and stronger line emission of carbon monoxide (CO) relative to their mass content of molecular hydrogen (H_2). However, these differences are likely to be caused by the more vigorous star formation present in the central regions of these galaxies. Thus, it would be interesting to

Fig. II.6.1: This mosaic of the inner part of M 51 was constructed from images taken with Hubble's Wide-Field Planetary Camera 2. The radiation of ionized hydrogen (H-alpha line emission) is shown in red, the visual and blue continuum light is shown in green and blue, respectively.

Credit: N. Scoville et al., 2001

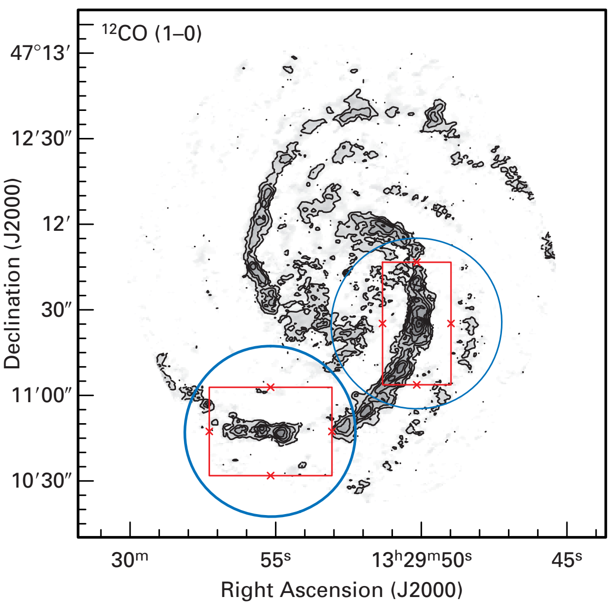
know whether GMCs residing in galactic disks with enhanced star formation are similar to local GMCs or closer to those found in the central regions of external disks.

In order to clarify this issue, Eva Schinnerer at MPIA together with colleagues at MPIfR, the University of Göteborg and the California Institute of Technology have performed a detailed interferometric study of the GMCs located in the disk of M 51, the Wirlpool Galaxy. M 51 is an ideal target for this kind of analysis, being one of the closest nearly face-on grand design spiral galaxies. A significant fraction of the molecular gas in M 51 is concentrated in its spectacular spiral arms, and since at its distance of only 25 million light-years, an arcsecond corresponds to only about 120 light-years, the physical properties of the molecular gas within the spiral arms can be studied in great detail.

Numerous star clusters and regions of active star formation (HII regions) have been identified in the spiral arms of M 51, as it is obvious from high-resolution images obtained with the Hubble Space Telescope (see Fig. II.6.1): the analysis of such images has established that younger clusters are more deeply embedded (since they show higher extinction by interstellar dust) and are located closer to spiral arms. And a large number of giant molecular cloud associations can be identified in the existing maps of their line emission (see Fig. II 6.2).

The interferometric observations of the molecular line emission in M 51 were obtained with the millimeter interferometer of the Owens Valley Radio Observatory (Ovro). Two prominent regions located in one well designed spiral arm were selected, which are indicated in Fig. II.6.2. The upper (western) region contains the brightest peak of carbon monoxide (CO) emission, and the southern region comprises three large GMC associations.

Fig. II.6.2: Integrated ^{12}CO(1-0) line emission map by S. Aalto et al., on which the location of the two Ovro pointings (dark circles) is overlaid. The size of the circles corresponds to the primary beam at 3 mm wavelength. The light gray rectangles outline the western and southern regions that are studied in detail.



Credit: E. Schinnerer

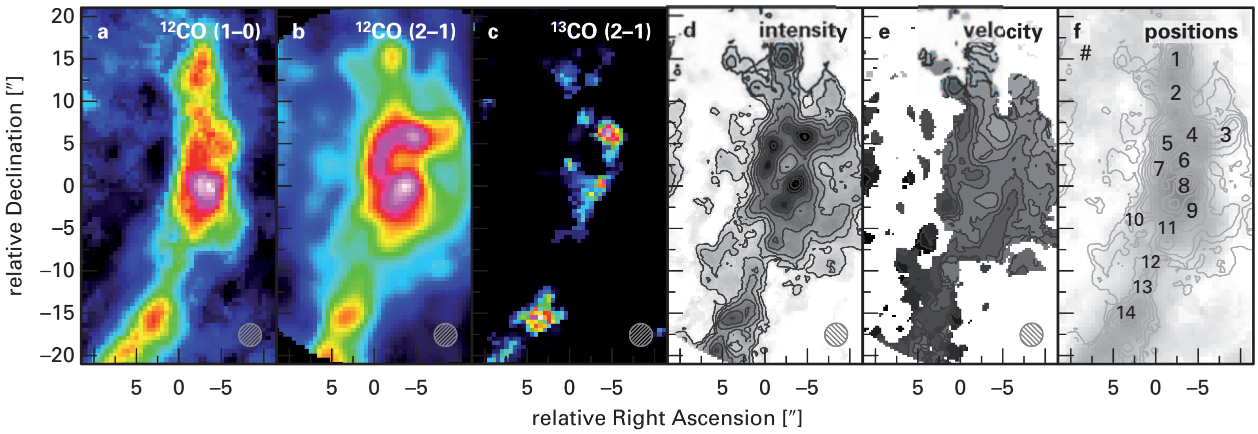
In each region, emission lines of ^{12}CO, ^{13}CO, C^{18}O, HCN and HCO_+, the key tracers for molecular gas, were mapped interferometrically. Fig. II.6.3 shows selected data sets collected in the western region. First, the maps obtained in the light of different molecular emission lines were inspected in detail for morphological differences (see Fig. II.6.3 a-c): when comparing the brightness distribution of different lines, small changes in morphology were found, which is not surprising considering that physical conditions are changing along the spiral arm; at 1.6″ resolution (Fig II.6.3d) a break-up into smaller peaks and a split into two lanes over a region of about 1200 light-years emerges.

Inspection of the derived velocity field revealed some large scale velocity gradients (Fig. II.6.3e). The high-resolution data with a resolution of 200 light-years show that some GMAs move faster or slower than average, but a few peculiar velocities are probably due to a superposition of GMCs rather than actual streaming motions. A small large-scale velocity gradient of about 50 kilometers per second is present in the region shown.

From the line ratios observed, temperature gradients were derived (Fig. II.6.3f), revealing a decrease of the kinetic temperature with distance from the galactic center from about 27 K at 3000 light-years to less than 10 K at 4500 light-years, while there is no large difference in temperature or in molecular density of GMCs close to regions of active star formation.

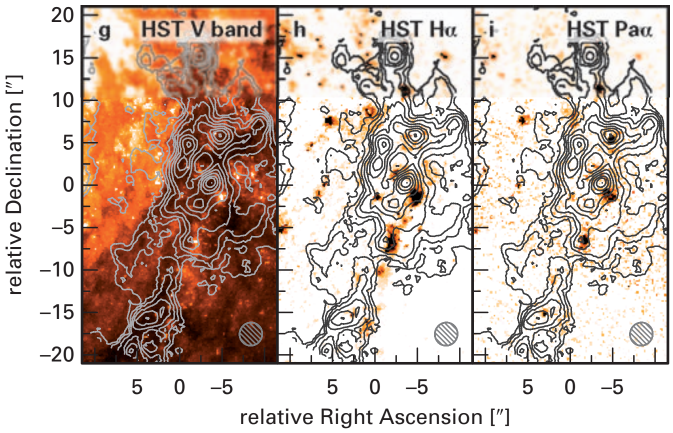
As expected, the comparison of the interferometric CO data with the high-resolution HST image in visual light shows that the molecular gas coincides very well with the prominent dust lanes seen in the individual spiral arms (Fig. II.6.3g). Most of the active star-forming regions, which are traced most clearly by Paschen-alpha emission and by the thermal radiation of warm dust (see Fig. II.6.3h and II.6.3i) lie downstream of the molecular gas, as one expects if star formation is occurring inside the molecular gas spiral arms.

Altogether, the detailed analysis of the interferometric observations shows, that the physical properties of the GMC complexes of M 51 are very similar to those observed for GMCs in our Galaxy. In particular, the ratio between the strength of CO line emission and the mass of molecular hydrogen is similar to the standard ratio derived for the GMCs located in the spiral arms of our Galaxy. At the spatial resolution of 200 light-years, the ^{12}CO data show that at these scales the GMC associations brake up into clumps that are roughly aligned along the spiral arms. Based on the observations presented here, most of the GMCs in the spiral arms of M 51 are cold, dense structures, that are not heavily affected by the neighbouring starforming regions. Comparison of the



Credit: E. Schinnerer

Fig. II.6.3: Selected observational results for the western region. *a-c)*: Molecular emission of ^{12}CO and ^{13}CO at 2.9 arcsec resolution; *d)*: integrated intensity map, and *e)*: velocity field at 1.6 arcsec resolution (the iso-velocity contours are in steps of 5 kilometers per second); *f)* the kinetic gas temperature, which in this area was determined at 14 positions, was found to decrease from 27 Kelvin at position 1 to less than 10 Kelvin at position 14; *g-i)*: the ^{12}CO line emission, represented by contour lines, is compared to the stellar light distribution in the HST visual band *g)*, to the Paschen-alpha emission of star-forming regions *h)*, and to the thermal emission of warm dust heated by newborn embedded stars *i)*.



extinction inferred from the derived density of the molecular gas with that derived for the ionized gas in star forming regions shows, that the extinction towards the molecular clouds is at least 5 times higher than the extinction towards regions of active star formation.

Eva Schinnerer,
in collabortion with:
Axel Weiß, MPI for Radio Astronomy, Bonn,
Susanne Aalto, Göteborg University,
Nick Z. Scoville, C.I.T, Pasadena

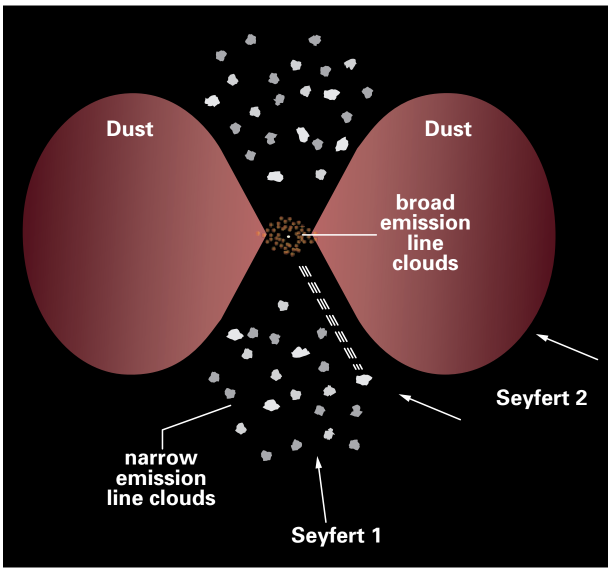
II.7 The Heart of Centaurus A

Exploring the surroundings of the central black hole

Since only few years the nearest active galaxies can be studied with sufficient spatial resolution to test the models developed for the physical structure of their nuclear regions. Here we report on observations of the nuclear region of Centaurus A in the mid-infrared, which were performed using the MIDI interferometer at the VLT.

In recent years a unified model has been developed in order to explain the extreme luminosities and other highly energetic phenomena observed in Active Galactic Nuclei (AGNs) – the virtually pointlike central regions of quasars, radio galaxies and other so-called Active Galaxies. In the frame of this model it is assumed, that the central engine which is responsible for the nuclear activity consists of a massive black hole surrounded by an accretion disk and by gaseous clouds moving at high velocity and emitting a spectrum which is characterized by very broad emission lines. These extremely compact components are surrounded by huge amounts of dust distributed in a toroidal structure. Farther out, the interstellar clouds emit narrow lines, since their gas moves at much lower velocities. Galaxies whose spectra are dominated by the emission lines typical of "broad line regions" are referred to as of 'type I', while the galaxies whose central region is obscured by the dusty torus are called 'type II'. Thus, in the frame of this model the orientation of our line of sight with respect to the central engine and its surroundings is decisive for the observable properties of individual AGNs (see Fig. II.7.1). In order to test this model, its geometrical characteristics have to be verified observationally. This requires that at least the structure of the postulated "dusty torus" has to be resolved spatially.

Fig. II.7.1: In the frame of the unified model, Active Galactic Nuclei are powered by a central supermassive black hole surrounded by a compact accretion disk and by huge amounts of dust forming a thick extended ring or torus around the central engine. Depending on wether our line of sight reaches the central region directly, or whether it crosses the toroidal dust distribution, we observe the characteristics of Type I or Type II Active Galactic Nuclei.



Credit: K. Meisenheimer

When the central black hole is active, i. e. when it is accreting huge amounts of matter from its surroundings, the compact accretion disk is heatet up to as much as 100 000 Kelvin, and consequently becomes a strong source of highly energetic thermal and nonthermal radiation, by which in turn also the large dusty torus farther out is heated up. At distances of, say, 10 light-years from the central black hole, the heated dust reaches temperatures of about 300 Kelvin and its thermal radiation is best observed in the mid infrared, at wavelenths between 5 and 30 micrometers. However, even at the distance of the nearest active galaxies known, 10 light-years correspond to an angle of 40 milli-arcseconds – this is the angle subtended by a one Euro coin observed from 120 kilometers away. But even at 5 microns, the shortest suitable mid-infrared wavelenth, the resolving power of a single 8.2 meter telescope of the VLT is not better than 100 milli-arcseconds, by far not enough to test the unified model described above. Thus, a more powerful istrument is needed to test the unified model.

MIDI, the VLT interferometer for the mid infrared

In 2003 a new istrument called MIDI was installed at the VLT. This "Mid-Infrared Interferometric Instrument" had been developed by a Dutch-French-German collaboration, in which the MPIA had a leading role. With MIDI the infrared light collected by any two of the four 8.2 m Unit Telescopes of the VLT in the 8 – 13 micron wavelenth range can be brought to interference, thus leading to a much higher angular resolution than what can be achieved with a single Unit Telescope. If observations are performed with all four 8.2 m telescopes combined pairwise, and all collected data are evaluated together, the resolving power of a single 125 m telescope is obtained (see Fig. II.7.2). In order to obtain a better coverage of the synthetized collecting area (orange circle in Fig. II.7.2), astronomers take advantage of the Earth's rotation, which in the course of the observing runs causes a rotation of the single telescopes (as seen by the observed object) within the total collecting area. Since MIDI

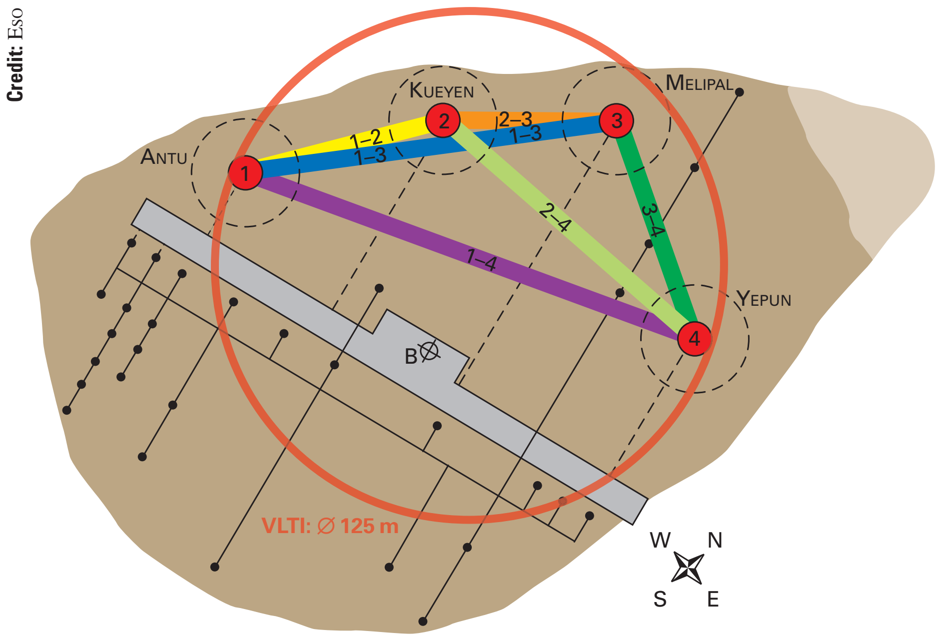


Fig. II.7.2: The light paths of all four 8.2 m telescopes of the VLT can be combined in the Interferometry Lab of the VLT on top of Cerro Paranal. Here, with Midi the light from any two telescope units can be brought to interference in the 8 – 13 micron wavelength range, and the resolving power of a single 125 m telescope (*orange circle*) is obtained / Eso).

allows to combine only two telescopes at a time, the six possible combinations must be realized in the course of several observing nights. At a wavelength of 12.5 microns, such observations with Midi yield an angular resolution of better than 20 milli-arcseconds, which according to the estimates given above should be sufficient to resolve spatially the postulated toroidal dust distributions in the nearest AGNs.

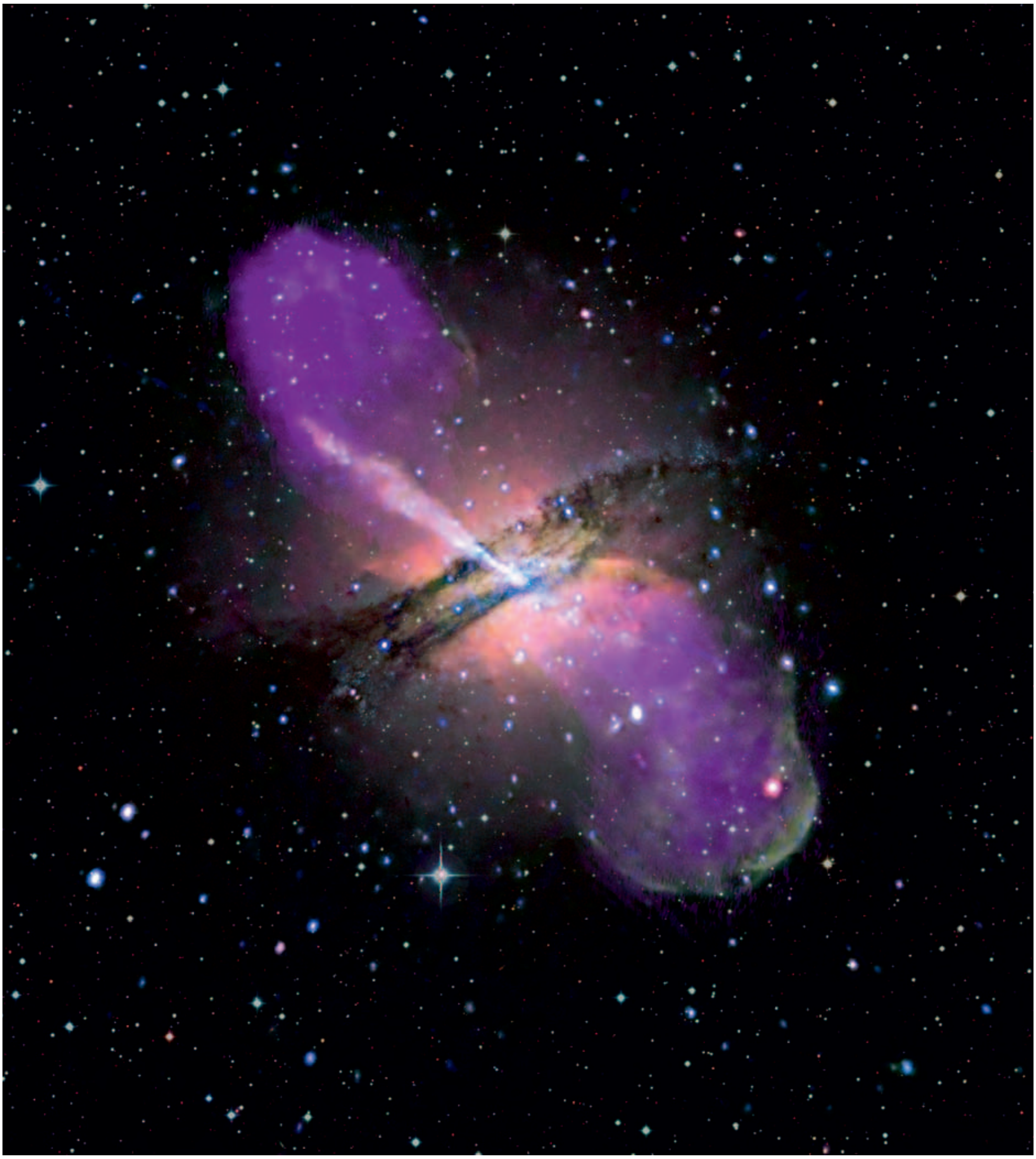
The case of Centaurus A

At the distance of less than 12 million light years, NGC 5128 is the elliptical galaxy nearest to us. Its second name, Centaurus A, is due to the fact that it is the brightest radio source in the southern constellation of Centaurus. What we observe today is actually two galaxies, a large elliptical and a smaller dusty spiral, in the act of merging (see Fig. II.7.3). The merging process, which extends over several orbits of the two galaxies around each other, is estimated to have begun several hundred million years ago. The huge dust belt, a conspicuous remnant of the spiral galaxy, heavily obscures the image of the elliptical galaxy in the visual light, but it is transparent in the mid infrared range. At the center of the system a black hole of 200 million solar masses emits a bipolar jet of highly relativistic electrons, which is so prominent in the xray emission and also powers the radio emission of the extended radio lobes. The jet testifies, that the central black hole is actually accreting matter at a very high rate.

These strong signs of nuclear activity are characteristic of the AGNs for which the unified model described above was developed. At the distance of Centaurus A the angular resolution of 12 milli-arcseconds, which should be achieved by Midi in the mid infrared, corresponds to a linear size of 0.8 lightyears. Since no other AGN is nearer to us, Centaurus A represents the first and only choice for attempting to resolve spatially with Midi the warm dusty torus which according to the unified model structures should surround the central machine.

The nuclear region of Centaurus A had been studied with Midi in the mid infrared already in 2007 by researchers at the MPIA and other colleagues. However, the data collected in that first run provided only a limited coverage of the virtual 125 m "telescope" shown in Fig. II.7.2. So, a second, much more complete set of data was collected, that allowed to to fit model source brightness distributions to the nuclear mid-infrared emission and determine the parameters of the possible emission components much more precisely. These observations provide an effective angular resolution at 12.5 microns of 6.7 to 15.5 milli-arcseconds, which corresponds to 0.4 to 0.8 lightyears at the distance of Centaurus A.

The entire data set was used to fit two-component models to the nucleus of Centaurus A, consisting of an unresolved point source (which represents the central machine and its immediate ultra hot surroundings) and an extended component (which represents the warm dust distribution at larger distances). The best result of this fit is shown schematically in Fig. II.7.4. The central point source contributes 47 percent of the total observed



Credit: NASA/CXC/CfA/R. Kraft/NSF/VLA/Univ. Herfordshire/M. Hardcastle/ESO/WFI/M. Rejkuba

Fig. II.7.3: This composite shows an optical image of Centaurus A, on which both, the radio and the X-ray image are superimposed. The optical image is dominated by the huge dust belt crossing the entire elliptical galaxy, which is the most prominent remnant of the swallowed spiral. The radio image consists mainly two huge lobes extending about ten times the size of the stellar component in both directions. The X-ray image is dominated by the bipolar jet emitted by the active nucleous of Centaurus A, which extends far out and powers the radio emission in the lobes.

flux and is embedded in an elongated disk which is almost completely resolved. It is 4.3 light years long and 1.9 light years wide. Its major axis is oriented 10 degrees east of north and forms an angle of 40 degrees with the axis of the large scale radio jet. The new data indicate the existence of smaller scale structures within the extended component, that are not described by the simple geometrical model assumed. The parameters derived for the disk should therefore be interpreted only as tentative evidence for such a structure.

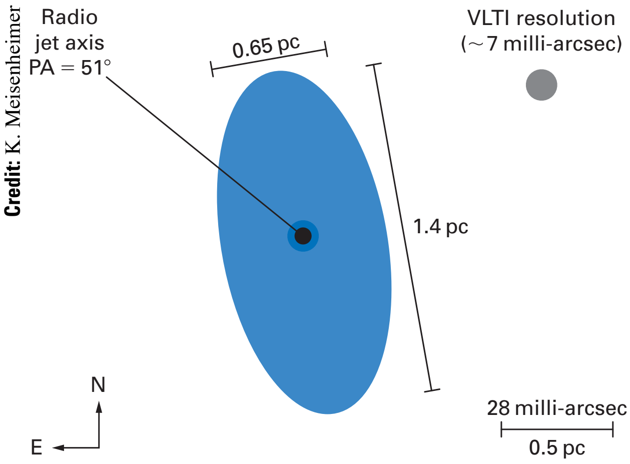


Fig. II.7.4: The mid-infrared emission observed with MIDI from the nuclear region of Centaurus A can be described in terms of two components – an unresolved point source that can be identified with the central machine, and a resolved, elongated structure 4.3 by 1.5 light years in size, whose major axis forms an angle of 40 degrees with the axis of the large scale bipolar jet emanating from Centaurus A.

This first step towards a thorough observational study of the structure of AGNs leads us to the limits of the angular resolving power of present-day instrumentation. A more detailed picture must probably await the largest telescopes of the next generation.

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II.8 Fire Without Smoke

The most primitive black holes in the universe

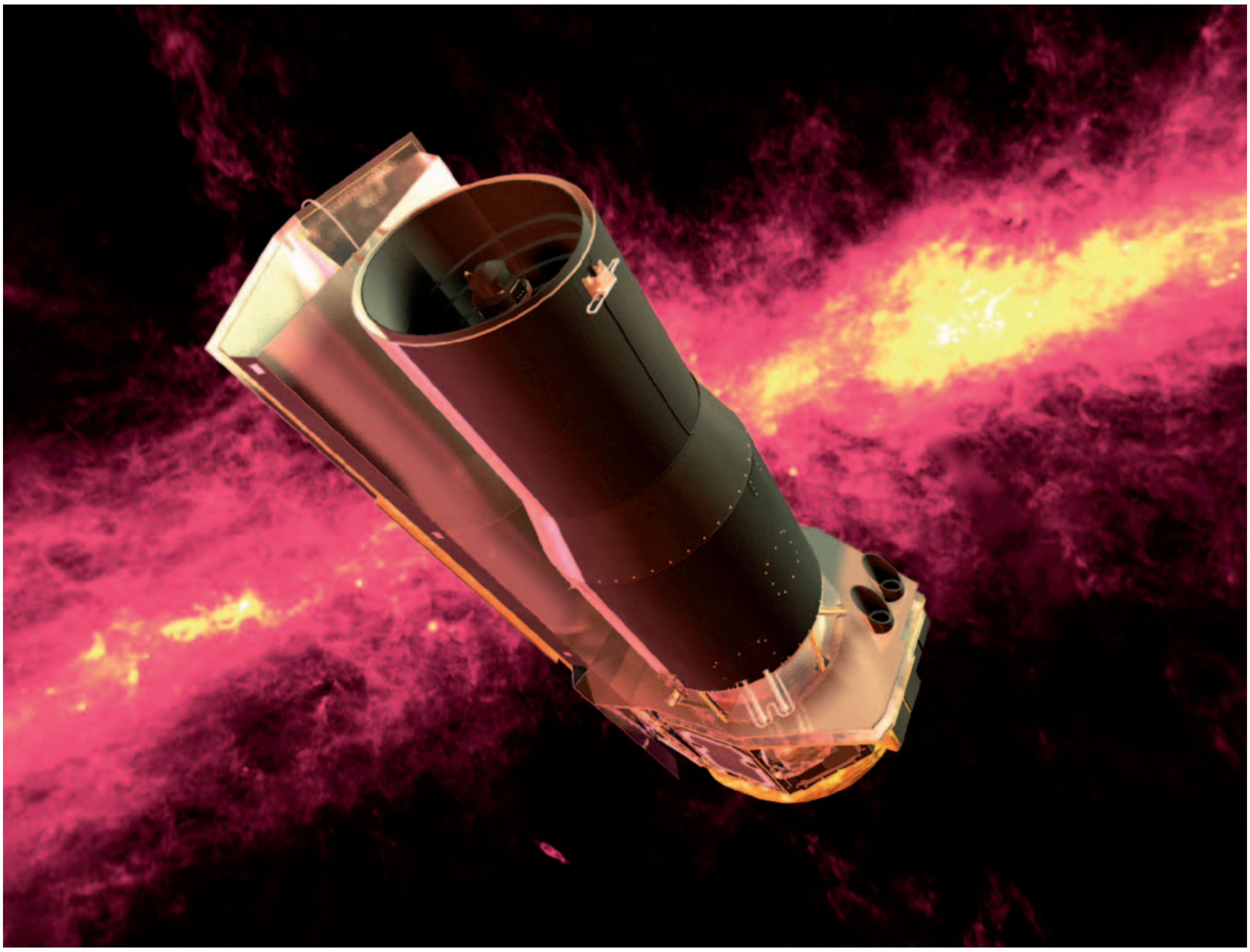
Astronomers have found what appear to be the two most primitive black holes known in the universe. Located at a distance of 12.7 billion lightyears from Earth, we see these black holes or, more precisely, the bright galactic nuclei powered by these black holes, as they were 12.7 billion years ago, less than a billion years after the big bang. The existence of such primitive black holes had long been surmised, but until now, none had been observed.

Quasars are the core regions of galaxies which contain active black holes. Such black holes are surrounded by brightly glowing "accretion disks": disk of swirling matter that is spiraling towards the central black hole. Such disks are among the brightest objects in the universe; in consequence, quasars are so bright that even at great distances, it is possible to investigate their physical properties in some detail.

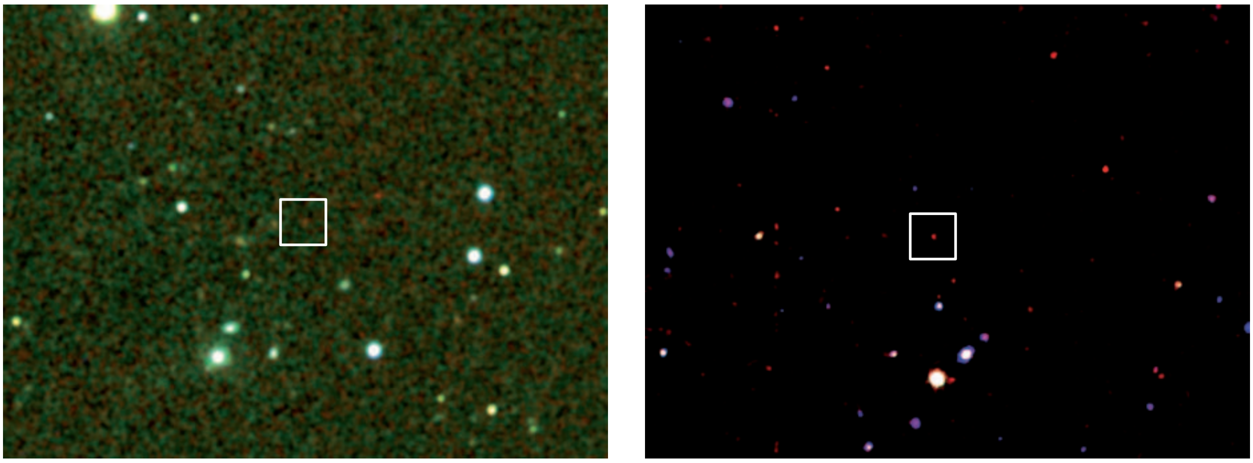
It takes about 13 billion years for light from the most distant known quasars to reach us. In other words: We see these quasars as they were about 13 billion years ago, less than a billion years after the Big Bang. Looking that far into the past, one might expect to see half-formed, rather primitive precursors of more recent quasars. But in 2003, when the first of these very distant quasars were observed, researchers were greatly surprised to find that they were not markedly different in appearance from their modern relatives.

Now a team of astronomers led by Linhua Jiang (University of Arizona, Tucson), which includes researchers from the MPIA and the Max Planck Institute for Extraterrestrial Physics in Garching, has, for the first time, observed what appear to be very early, primitive

Fig. II.8.1: The Spitzer Space Telescope against an infrared sky (*computer-generated image*). With Spitzer's help, astronomers have now found the most primitive black holes in the universe.



Credit: Nasa / JPL-Caltech



Credit: MPIA / M. Pössel / SDSS

Fig. II.8.2: Optical Images of the two quasars (J005-0006 *left*, J0303-0019 *right*) look quite unspectacular – the objects are barely distinguishable from the background noise in these false-colour images. It takes spectroscopy to show that these are two extraordinary quasars indeed.

quasars: quasars in an early stage of evolution, which are markedly different from quasars at later epochs.

The astronomers used NASA's SPITZER Space Telescope (Fig. II.8.1) to observe infrared light from those extremely distant quasars. One of the quasars is SDSS J 0005-0006 (where SDSS denotes the Sloan Digital Sky Survey, which first discovered this quasar), the other is SDSS J 030-0019 (see Fig. II.8.2). These quasars have redshift values of $z = 5.85$ and $z = 6.05$, respectively. If we use the time it takes for the light to reach us from the quasars, the two distant galaxies which harbour these quasars are 12.7 billion lightyears away.

At such great distances, it is impossible to make out the different parts of a distant galaxy, but one can derive information about these objects from their spectra, that is, from measurements of how much light an object emits at different wavelengths. For example, hot dust emits light at infrared wavelengths.

Astronomers can model the way in which the quasar's different regions, such as the accretion disk, dust and gas, contribute to the object's total infrared emission. For ordinary quasars, there is very good agreement between the prediction of these models and observations; for the two quasars, there is good agreement between the observations and those models in which it is asumed that there is no dust at all.

The spectra used here were obtained in the infrared region (see Fig. II.8.3). The spectrum's properties – more light emitted at some colors, less light at others – provide telltale signs about the chemical composition and other properties of the matter producing the light, such as the presence of dust. With these infrared observations, one can identify the signature of hot dust, which is a standard feature of modern quasars – in such quasars, the glowing disk, which is comparable in size to our whole Solar System and harbours the central massive black hole, is surrounded by a gigantic dust torus (which is about a thousand times larger). In two of the 20 quasars observed the dust signature proved to be conspicuously absent. This suggested that these two quasars might be very primitive: The very early universe contained no dust at all, so the first stars and galaxies should have been dust-free. They should be intensely hot and radiate brightly, but contain no dust particles: fire without smoke. The existence of such lowdust or even dust-free quasars had long been surmised, but such objects had not been observed – until now.

If these two quasars indeed represent a very early, dust-free stage of quasar evolution, then quasars like this should only be found when looking into the distant past, that is, at the centers of very distant galaxies. To make sure, the researchers examined the 20 very distant quasars and all the 362 much closer quasars for which the same kinds of observational results have been published. The comparison shows that the two dustfree quasars are indeed markedly different from all the other quasars, and in particular from all the much nearer quasars. By this measure, it is very likely that their special properties are indeed related to the fact that we are looking almost 13 billion years back in time.

Quasar evolution in action

Nothing that has entered a black hole can escape, and so black holes grow steadily in mass. In the very distant quasars but, significantly, not in their more modern counterparts, black hole mass is strongly related to the amount of hot dust present: more mass, more dust. This indicates a coevolution: We are looking at quasars with central black holes that are initially very small, but grow very rapidly in mass as they swallow more and more

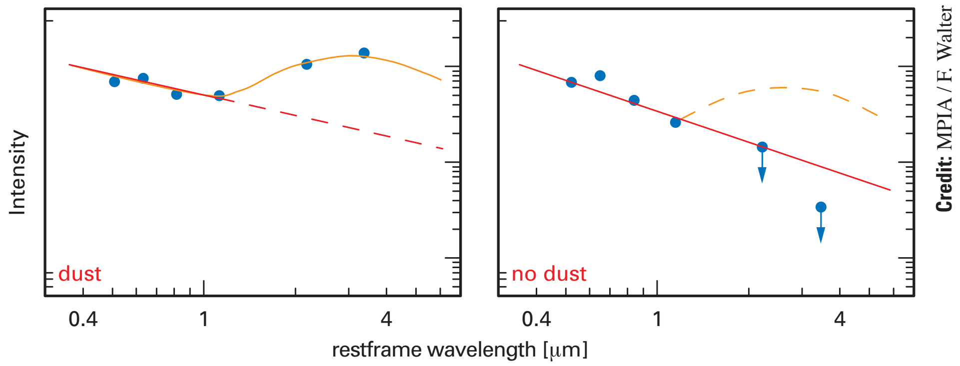


Fig. II.8.3: Comparison of the infrared spectra of two distant quasars. The curve indicates the predictions derived from models of quasars that either do or do not contain dust. The left panel shows J 1250+3130: the orange part of the curve indicates the "bump" in the spectrum that is the tell-tale sign of hot dust. The right panel shows the spectrum of J 0005-0006. The bump is absent; clear indication that this quasar is virtually dust-free.

matter. At the same time, more and more dust is produced. There are two likely production mechanisms: in outflowing winds, streams of highly ionized atoms that are blown outwards from the quasar's central region and that provide conditions suitable for the formation of dust, or in starforming regions very close to the central black hole, where dust is produced by young stars.

Thoroughly examining all available data, the astronomers found that none of the quasars that are closer to Earth – so that we see them at a later stage of their evolution – come even close to being as dustfree as J 005-0006 and J 0303-0019, the two youngest and most distant quasars. Also, they found that, for the very distant quasars, there is a strong correlation between the mass of the quasar's central black hole and the amount of dust present. This indicates an evolutionary process, in which the central black hole grows rapidly by swallowing up surrounding matter, while, at the same time, more and more hot dust is produced over time. From studies on galaxies that are closer to Earth than these distant quasars, astronomers have been able to derive a relation between the speed of rotation of the swirling accretion disk surrounding a supermassive black hole and the black hole's mass. For the distant quasars, certain features of the spectrum indicate the accretion disk's rate of rotation (using the so-called Doppler effect); from these measurements, the black hole mass is deduced.

All available evidence points towards the conclusion that finally, astronomers have managed to see quasar evolution in action, and that the two dustfree quasars indeed represent the most primitive black hole systems we know: quasars at an early stage of their evolution, too young to have formed a detectable amount of dust around them.

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MPE (Garching), Drexel University (Philadelphia),
Harvard-Smithsonian CfA, Princeton and Copenhagen

III. Selected Research Areas

III.1 Unraveling the mysteries behind the dust

With the turn of the year 2009/2010, the Herschel Observatory took up its full routine science operations, which will presumably last until the boil-off of the liquid helium coolant at the beginning of 2013. The operations of the Pacs instrument, taking about 50 % of all Herschel observations in 2010, went absolutely smoothly and were very stable. First scientific highlights of the mission were published in a special issue of the journal Astronomy & Astrophysics and were presented during the big Herschel dedicated conference ESLAB2010.

Operations of the Pacs instrument

The members of the Pacs Instrument Control Centre Team located at MPIA coordinated the instrument calibration during the routine science operations, which were composed of special programs for a more refined understanding of instrumental effects and in particular of observations monitoring the instruments stability and assessing trends. The Herschel observing time was divided into fort-nightly planning cycles, to each of which the MPIA team contributed about 10 to 20 hours of calibration observations and corresponding scheduling instructions. These were integrated into the overall schedule by the mission planners at the Herschel Science Centre at EsaC. The individual calibration items were compiled according to a permanently evolving calibration plan, which was maintained at MPIA. The allocation of the individual observing days by the three different instruments and the activities were agreed upon during weekly planning meetings. Because the blue Pacs photometer camera has the best spatial resolution of all Herschel instruments, the Pacs calibration team at MPIA also supported the programs for further consolidation and assessment of the telescope pointing accuracy.

The MPIA calibration team made a major contribution to the flux calibration of the Pacs photometer camera. For the whole year of 2010 a very good relative accuracy of better than 1% could be demonstrated. With the celestial calibrator data sets obtained until end of 2010, it was also possible to achieve an absolute calibration accuracy of better than 5%.

Another significant contribution in support of the Herschel observer community is the build-up of the Pacs instrument analysis software both in pipeline mode for populating the Herschel data archive and in the interactive mode for detailed individual reduction. This is complemented by scientific validation of data sets and data reduction instructions produced with new software versions prior to their release.

Fig. III.1.1: *Left*: Poster of the ESLAB2010 conference which was dedicated to the scientific results of the Herschel mission in its first year. *Middle:* Group photo of the ESLAB2010 participants at Estec. *Right:* Front cover of the special Herschel Astronomy & Astrophysics edition.

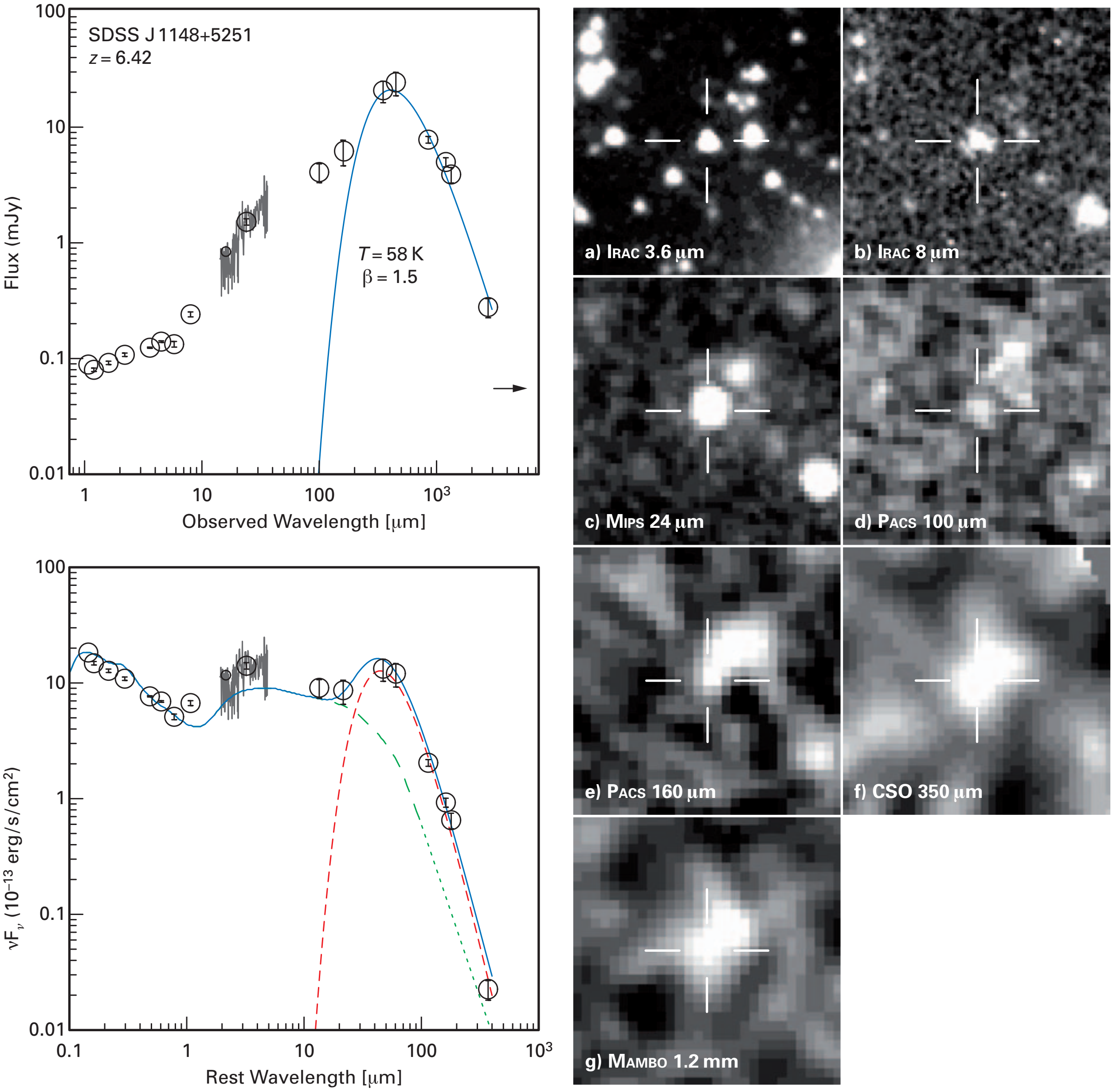
Credit: U. Klaas

Scientific Results

A scientific highlight was the submission of the first refereed publications for the Herschel Special Issue of the Journal Astronomy & Astrophysics. MPIA provided 7 first-author papers and contributed to 18 other papers, among them the Pacs instrument paper. Our observations in the framework of the Herschel Guaranteed and Open Time key projects were taken over the whole year. From May 4 to 7, 2010, the ESLAB2010 symposium took place at Esa's space technology centre Estec in Noordwijk. ESLAB is an annual meeting organized by the Research and Scientific Support Department (RSSD). ESLAB2010 was completely dedicated to the first scientific results of Esa's far infrared and sub-millimetre observatory Herschel. With 415 participants, it was the biggest conference ever at Estec, reflecting the huge interest in the scientific capabilities of the currently largest space telescope. MPIA researchers contributed 3 talks and 4 posters.

In the following the first published MPIA Herschel results are presented along several examples.

Fig. III.1.2: Spectral energy distribution of the z = 6.42 quasar SDSS J1148+5251. The solid line in the upper flux diagram represents a modified blackbody with a temperature of 58 K, which can be associated with the coldest dust component. The solid line in the lower luminosity diagram is a combination of this blackbody curve, which describes a starburst in the host galaxy, and the SED model of nearby quasars. *Right:* Images of the quasar in the wavelength range 3.6 to 1200 µm (Spitzer space telescope 3.6 – 24 µm, ground-based submillimetre telescopes CSO & Iram 350 – 1200 µm) with the two new Pacs images at 100 and 160 µm inclusive.



Credit: C. Leipski

Credit: U. Klaas

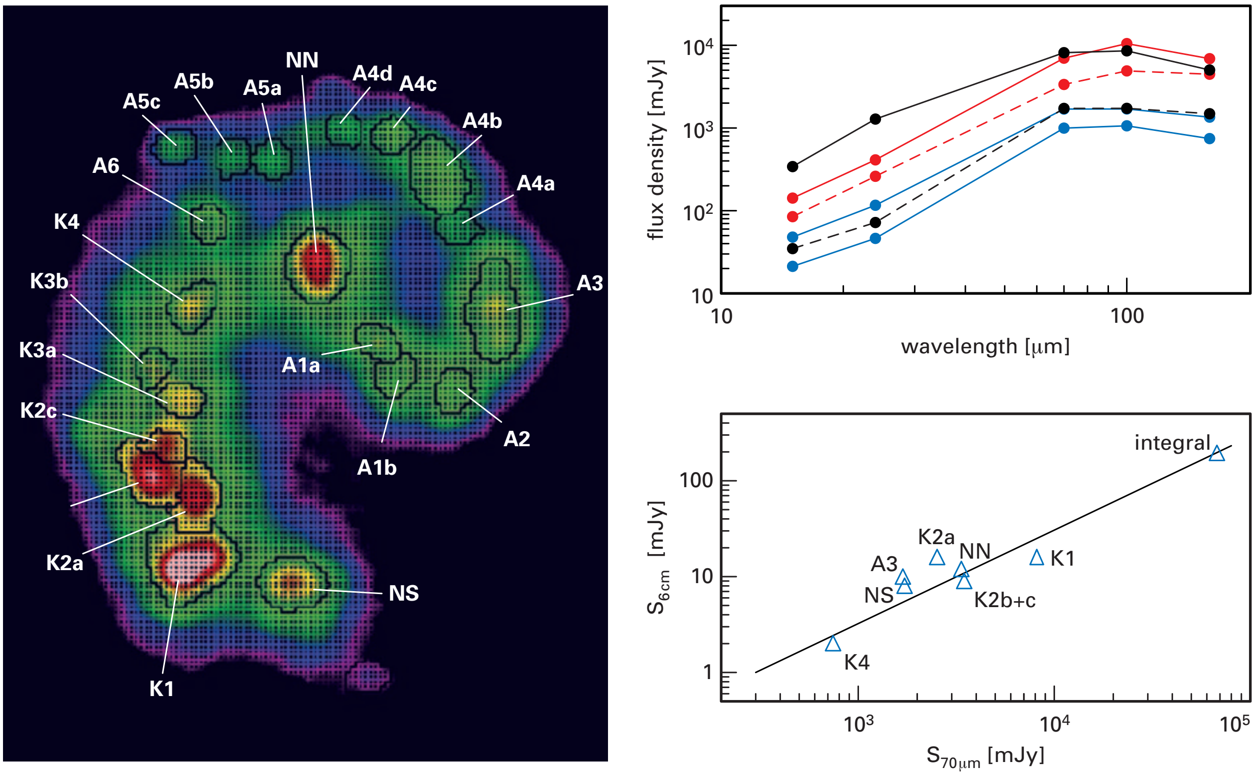


Fig. III.1.3: *Left:* Photometry of the emission knots in the interacting galaxy system of the Antennae Galaxy NGC 4038/39. *Top right:* Mid- and far-infrared spectral energy distributions of the brightest knots. *Bottom right:* Radio-to-far-infrared-correlation showing the deviation of the knots K1 and K2a due to their young age.

Program "The Dusty Young Universe" – observations of quasars with redshifts greater than 5

A detailed 1 to 1000 μm spectral energy distribution, with key points at 100 and 160 μm contributed by the PACS observations, could be obtained for one of the highest redshift objects, SDSS J1148+5251 ($z = 6.42$). For rest wavelengths ≤ 20 μm this spectral energy distribution is similar to the ones of low redshift QSOs. In the far infrared, SDSS J1148+5251 and another high redshift quasar, BR 1202-0725 ($z = 4.69$), show an excess emission with regard to nearby objects, which points to a cooler dust component heated by star formation in the disks of the host galaxies.

Program "SHINING – Survey with HERSCHEL of the ISM in Nearby Infrared Galaxies" – Observations of the interacting galaxies in the Antennae system

The high spatial resolution PACS maps of the Antennae allowed an assessment of the physical properties of individual emission regions and an analysis of the star formation history and their age relative to the impact front of the two galaxy disks. Via multiwavelength analysis the quite young age of the two brightest star formation regions in the overlap area could be corroborated. The detailed analysis of an interacting system in the stage of merging of the two components is an excellent model case for theoretical simulations studying the triggering mechanisms of the star formation by the highly dynamical processes of the collision and its feedback into the interstellar medium.

Program "KINGFISH – Key Insights on Nearby Galaxies: a Far-Infrared Survey with HERSCHEL" – Mapping of the circumnuclear starburst in the barred spiral NGC 1097

In the nearby barred spiral NGC 1097, the interaction of a bar, along whose potential interstellar matter is flowing inwards, and a ring of circumnuclear starburst, presumably fed by this inward flow, can be studied. For the first time, the sharp resolution of the maps in the three PACS bands allowed an accurate determination of the contribution of this circumnuclear ring, with a radius of 900 pc, of 75, 60 and 55 % to the total emission in the maximum of the spectral energy distribution. Only a small variation of the mid- and far-infrared flux ratios was found along the ring, pointing to an only moderate variation of the radiation field over scale lengths of about 600 pc. Hence, no significant age gradient was found, as would be expected by the "pearls on a string" model of stellar clusters between the two contact points of the bars with the ring. The upper limit of the contribution from the central region, containing a Seyfert nucleus, could be lowered by an order of magnitude with

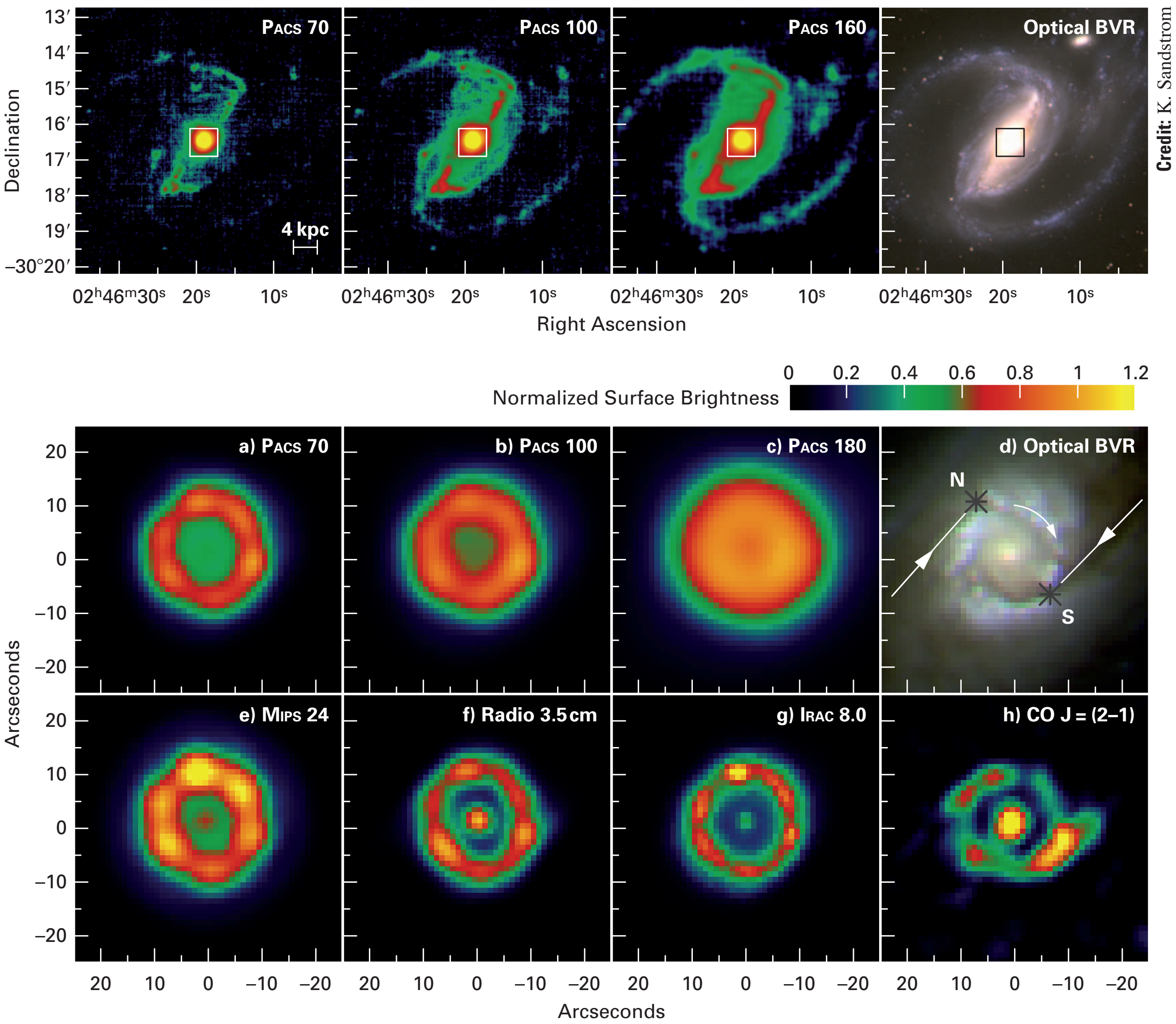


Fig. III.1.4: *Top:* Images of the barred spiral NGC 1097 in the 3 Pacs bands around 70, 100, and 160 μm, to the very right an optical image for comparison. The square box shows the excerpt of the images underneath. *Bottom*: Resolving the circumnuclear star formation ring in the 3 Pacs wavelength regimes and other selected wavelength ranges. The sense of rotation of the ring as well as the contact points of the bars are indicated on the optical image.

these high spatial resolution Pacs far-infrared observations. Spectroscopic observations of the brightest far infrared cooling lines from the interstellar matter in the ring with the Pacs spectrometer confirmed a clumpy structure of the ring gas and a rapid rotation.

Program "EPoS – Early Phases of Star Formation" – Observations of the infrared-dark cloud IRDC 18223

Pacs and Spire images of the infrared-dark cloud IRDC 18223, which is associated with the source Iras 18223-1243, complemented by Spitzer 24 μm- und Scuba 850 μm maps show very impressively the evolution of the youngest and cold massive star formation regions of this long stretched filament. Detected sources range from massive but still starless cores, which are shadows in the mid infrared maps, to massive cores with embedded protostars, which are strong emission sources over the whole covered wavelength range. The radiation of the youngest regions can be described as blackbody radiation of a temperature of 17 K. Exceptionally low total to submillimetre luminosity ratios confirm the youth of the partly up to 70 μm dark sources.

Program "EPoS – Early Phases of Star Formation" – Determination of the spatial distribution of the dust temperature in the globule CB 244

Herschel maps of the isolated low mass star forming Bok globule CB 244, together with a near infrared extinction map and long wavelength submillimetre and millimetre maps, allowed the generation of the first measured dust temperature map of a whole star forming molecular cloud. It contains both a protostar with an environmental tempe-

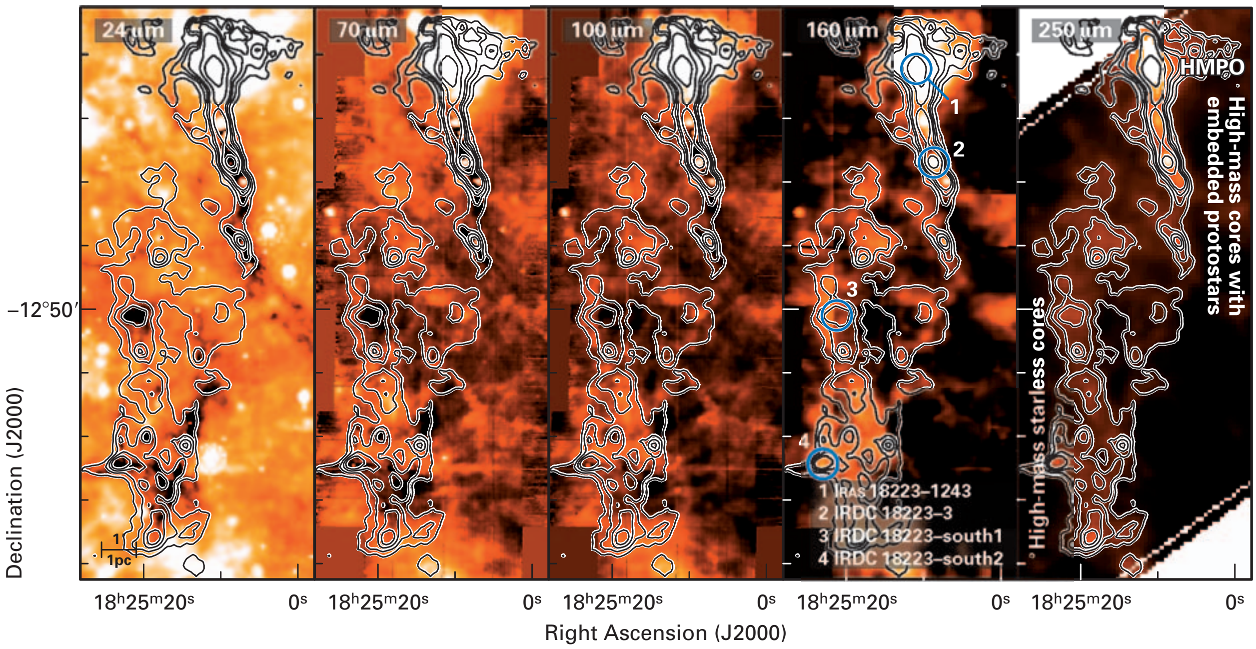


Fig. III.1.5: *Top:* Images of the infrared-dark cloud IRDC 18223 from 24 to 250 µm. Contours of an 850 µm-map are superimposed on each image. Dark regions inside the contours appear in absorption for this wavelength, colored and white regions in emission.

Credit: H. Beuther

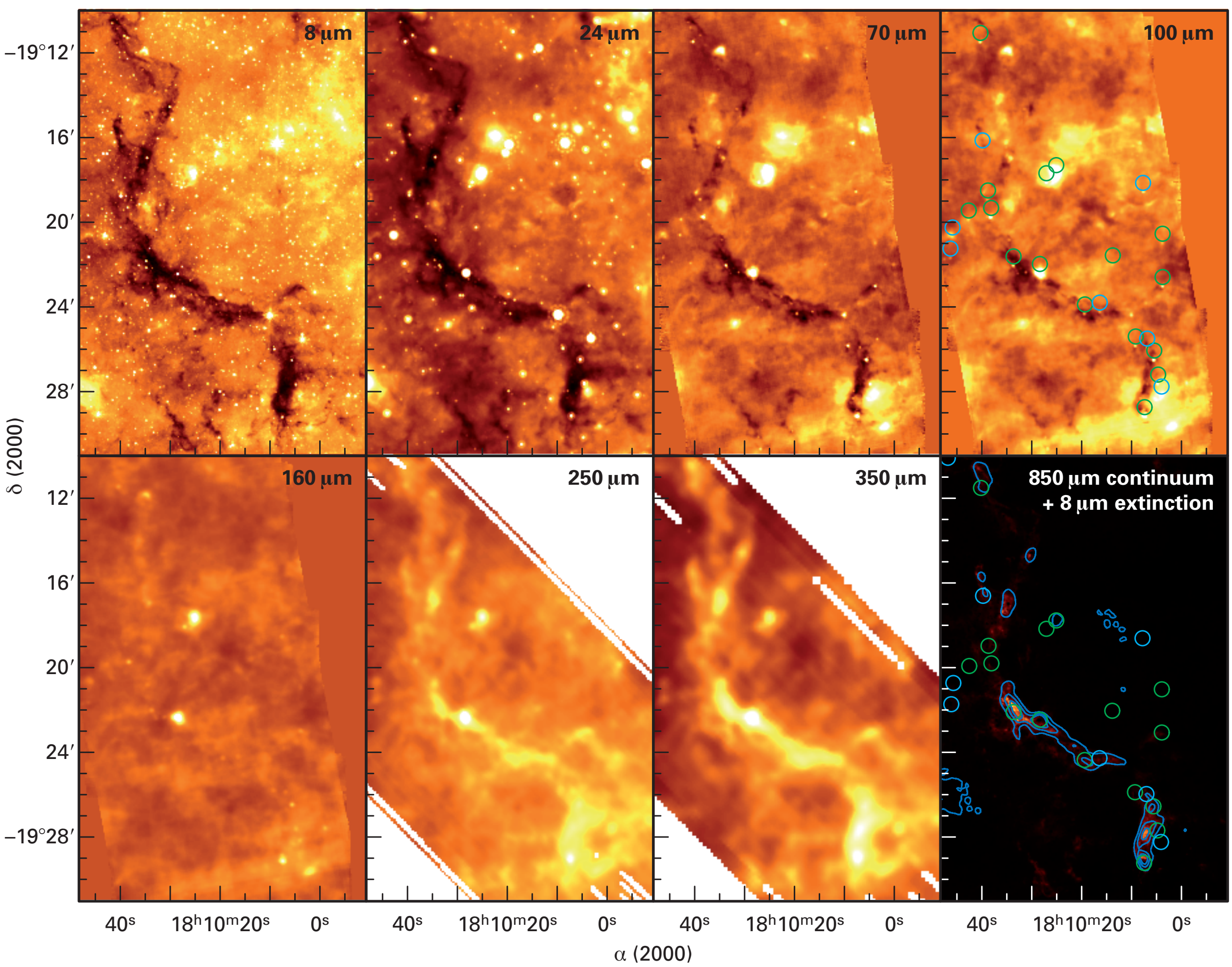


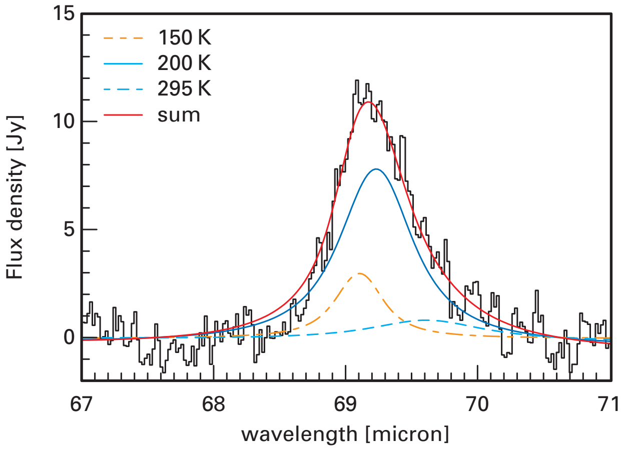
Fig. III.1.6: *Bottom:* Multi-wavelength presentation of the filamentary infrared-dark cloud G011.11-012 from 8 to 350 µm (8 and 24 µm Spitzer space telescope, 70 – 160 µm Herschel-Pacs, 250 + 350 µm Herschel-Spire). The dark absorbing regions in the 8 and 24 µm maps appear only fully in emission in the 250 and 350 µm maps.

Credit: S. Reagan, H. Linz

rature of 17.7 K and a starless core, in which the temperature drops to 10.6 K. The effect of external heating in dependence on the column density of the hydrogen gas could be studied. Mass estimates of the individual components concluded that somewhat less than half of the mass in the globule is participating in the star formation process.

Program "EPoS – Early Phases of Star Formation" – Localisation of the seeds of star formation in the filamentary infrared-dark cloud G011.11-0.12

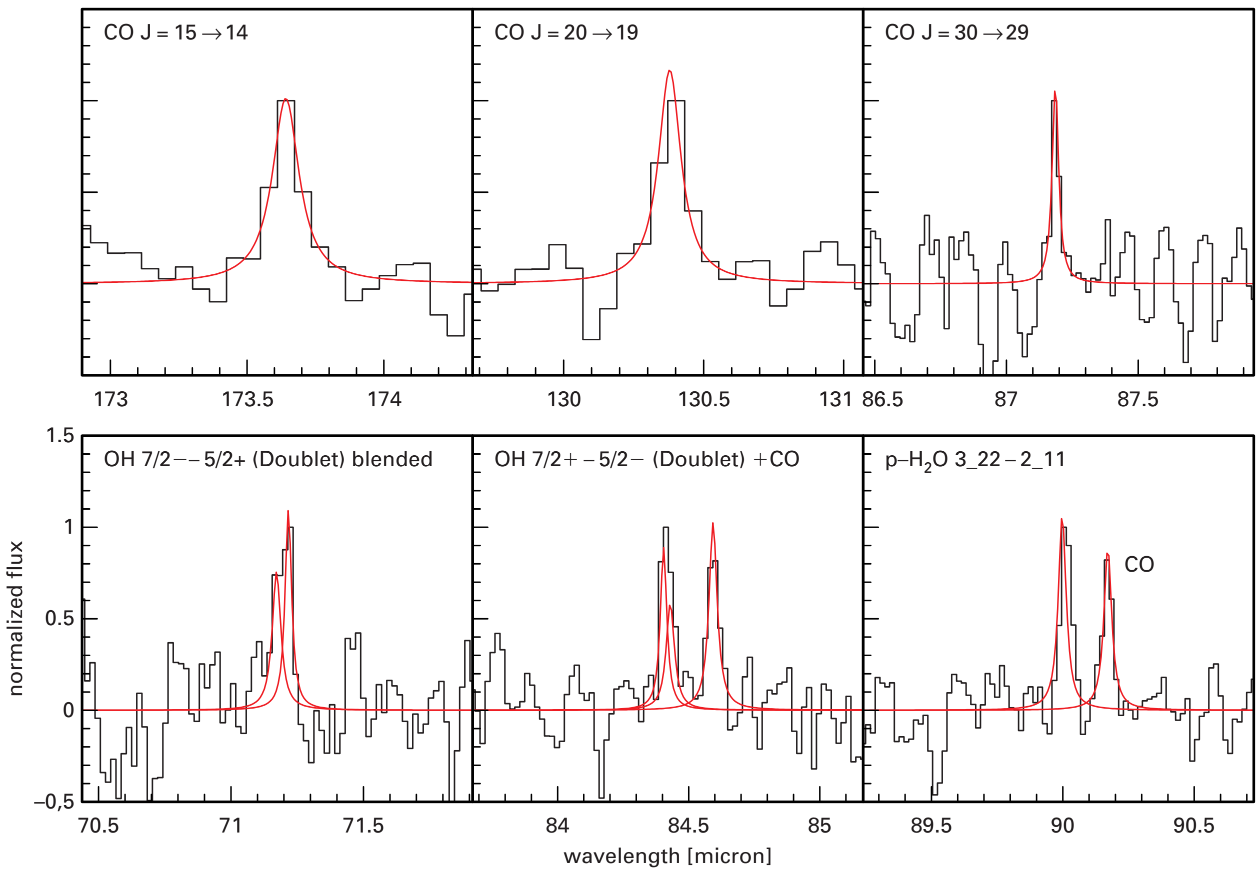
Herschel enables the accomplishment of large scale multiwavelength surveys in the far-infrared with unprecedented sensitivity and efficiency. 18 embedded pre- and protostellar cores were detected along the filamentary infrared-dark cloud G 011.11-0.12. Temperatures, luminosities and masses were derived from the obtained spectral energy distributions. Two cores have masses above 50 solar masses, making them the best candidates for massive stars in this filament. The derived masses are small with regard to the total mass of the cloud, suggesting a huge reservoir of matter not yet bound in pre- or protostellar cores.



Program "Digit – Dust, Ice and Gas In Time" – Dust and gas spectroscopy of the pre-mainsequence star HD 100546

A spectrum of the protoplanetary disk of the pre-main-sequence star HD 100546 over the whole wavelength range from 55 to 210 μm was obtained with the Pacs spectrometer camera. These measurements allow the determination of the evolution of dust, ice and gas around these young objects, which are still embedded in their parental molecular cloud core. More than 30 different spectral features of atoms, ions and molecules such as oxygen, carbon, water, hydroxyl and carbon monoxid could be detected. At a wavelength of 69 μm a strong emission band of forsterite, a crystalline olivine min-

Fig. III.1.7: *Left:* Spectral evidence of olivine crystals in the disk of the pre-main-sequence star HD 100546. The composition of different temperature components is indicated. *Bottom*: Selection of detected emission lines from the rich molecular line spectrum.



Credit: B. Sturm, J. Bouwman

Credit: O. Krause

Fig. III.1.8: Far-infrared image of the Andromeda galaxy in a colour composite from 70 µm (*blue*) and 160 µm (*green*) HERSCHEL-PACS and 250 µm (*red*) HERSCHEL-SPIRE maps, which shows a multiplicity of ring and spoke structures.

eral, was found. The shape and the central wavelength of the band permit conclusions on the temperature and the chemical composition of the matter. In any case, it is very iron-poor. The current observational data support two options: Either the olivines contain 2 % iron and have a temperature of 70 K at a distance of 50 AU to the star or the emission emerges from pure forsterite with a temperature of 200 K at a distance of 13 AU.

High spatial resolution mapping of the Andromeda galaxy

At the end of the year 2010, a 3° × 2° large scan map of the Andromeda galaxy was obtained, as another scientific highlight, by an MPIA Guaranteed Time program.

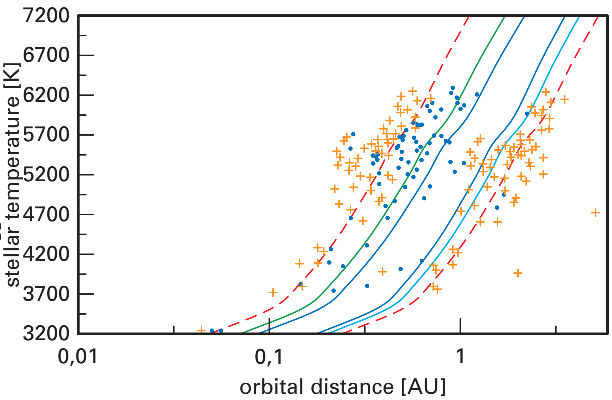
Oliver Krause, Ulrich Klaas, Markus Nielbock, Jürgen Schreiber, Zoltan Balog, Jeroen Bouwman, Hendrik Linz, Ulrich Grözinger, Christian Leipski, Johann Olofsson, Amelia Stutz, Marc-Andre Besel, Jan Pitann, Thomas Henning, Ralf Launhardt, Henrik Beuther, Sarah Reagan, Klaus Meisenheimer, Karin Sandstrom, Bernhard Sturm, Eva Schinnerer, Fabian Walter, in collaboration with the partner institutes of the PACS instrument consortium and the key project observation consortia SHINING, EPoS, KINGFISH and DIGIT.

III.2 Exoplanet Atmospheres and their Characterization

A decade of exoplanet search has led to surprising discoveries, from giant planets close to their star, to planets orbiting two stars, all the way to the first extremely hot, rocky worlds with potentially permanent lava on their surfaces due to the star's proximity. Observation techniques have reached the sensitivity to explore the chemical composition of the atmospheres as well as physical structure of some detected planets and to detect planets of less than 10 Earth masses (M_{Earth}), so called Super-Earths, among them some that may potentially be habitable. Confirmed nontransiting planets and several transiting Kepler planetary candidates orbit in the Habitable Zone of their host star. The detection and characterization of rocky and potentially Earth-like planets is approaching rapidly with future ground- and space-missions, that can explore the planetary environments by analyzing their atmosphere remotely. The results of a first generation space mission will most likely be an amazing scope of diverse planets that will set planet formation, evolution as well as our planet Earth in an overall context.

The current status of exoplanet characterization shows a surprisingly diverse set of giant planets. For a subset of these, some properties have been measured or inferred using radial velocity (RV), microlensing, transits, and astrometry. These observations have yielded measurements of planetary mass, orbital elements and (for transits) the planetary radius and during the last few years, physical and chemical characteristics of the upper atmosphere of some of the transiting planets. Specifically, observations of transits, combined with RV information, have provided estimates of the mass, radius and density of a subset of these planets, ranging from Giant planets to rocky planets like Corot 7b and Kepler 10b. Most detected planets orbit extremely close to their host star due to a detection bias and therefore receive high amounts of stellar irradiation and have subsequent high surface temperature.

Fig. III.2.1: Extent of the Habitable Zone for water loss limit for 0 % and 50 % cloud coverage (*inner limits*) and 100 % cloud coverage (*outer limit dashed line*) and position of potentially habitable Kepler planetary candidates in the HZ, individual HZ limits are indicated with crosses.



Credit: L. Kaltenegger

Recent investigations of high precision radial velocity data samples have shown that between 20 % and 50 % of all sample stars exhibit RV variations indicating the presence of super-Earths or ice giants. Among the hundreds of confirmed planets, already one close-by, low mass RV planet, Gl 581 d with a minimum mass of 7 M_{Earth}, orbits in the Habitable Zone of its parent star on the outer edge. These close-by planets provide excellent targets for future atmospheric exploration. Several Kepler transit planetary candidates from the February 2011 data release that are consistent with rocky models, orbit their host stars also in the Habitable Zone, providing first statistics of the number of planets and Earth-like planets (εEarth) and a more complete sample is expected in the second Kepler data release in 2012.

The discovery of transiting planets with masses below 10 M_{Earth} and radii consistent with rocky planetary models, answered the important question if planets more massive than Earth could potentially be rocky. 10 M_{Earth} are used from formation theories as the upper limit for rocky planet formation, for comparison, Uranus has about 15 M_{Earth}. Above that mass the planet is thought to accumulate a substantial amount of gas that makes it akin to a gas giant, not a rocky planet with an outgassed atmosphere. Where exactly such a cut-off mass is – if it exists at all – is an open question.

Recent discoveries by ground based observations, as well as by the Corot and Kepler mission, found planets with radii below 2 Earth radii and masses below 10 M_{Earth} and densities akin to Neptune as well as Earth, suggesting that there is not one cut-off mass above which a planet is like Neptune and below which it is rocky like Earth or Venus. The first planets below 10 M_{Earth}, with both mass estimates and radius measurements, have provided a wide range of observed radii and densities. Especially in the mass range below 5 M_{Earth}, two planets in the multiple planet system, Kepler 11 b and Kepler 11f, with 4.3 and 2.3 M_{Earth} have radii of 1.97 and 2.61 Earth radii and mean densities of 3.1 and 0.7 g/cm^3, respectively. These derived densities also allow substantial envelopes of light gases for this mass range. Recent atmosphere observations for a 6.55 ± 0.98 Earth mass planet, GJ 214 b,

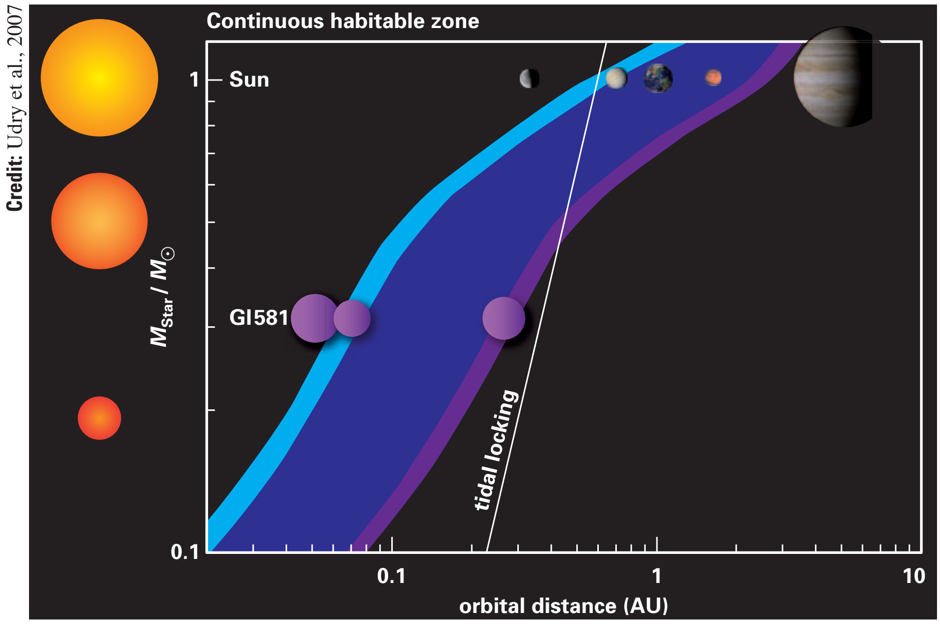


Fig. III.2.2: Stellar luminosity versus orbital distance. The extent of the inner edge of the HZ for the water loss limit for 0 %, 50 % and 100 % cloud coverage (*from right to left*) showing the Habitable Zone of the Solar system and the Gl 581 system. (*dark blue region with clouds is based on very simplistic models*)

with a mean density of 1.8 g/cm^3, indicates either hazes or high cloud cover in an expanded atmosphere.

Observing mass and radius alone can not break the degeneracy of a planets nature due to the effect of an extended atmosphere that can also block the stellar light and increase the observed planetary radius significantly. Even if a unique solution would exist, planets with similar density, like Earth and Venus, present very different planetary environments in terms of habitable conditions. Therefore the question refocusses on atmospheric features to characterize a planetary environment. The atmosphere is the only accessible quantity that allows exploring a planetary environment remotely, the aim of the new "Super-Earth and Life" group at MPIA.

The Habitable Zone (HZ)

Different aspects of what determines the boundaries of the HZ have been discussed broadly in the literature. The main differences among these studies are the climatic constraints imposed. Here we focus on the circumstellar HZ defined by J. Kasting in 1993 as an annulus around a star where a planet with a $CO_2/H_2O/N_2$ (Earth-like composition) atmosphere, surface pressures between 1 and 10 bar and a sufficiently large water content, like Earth, can host liquid water permanently on a solid surface. In this definition, the two edges of the HZ (see Fig. III.2.1) as well as the equilibrium temperature of the planet, T_{eq}, depend on the Bond albedo A of the planet, the luminosity of the star L_{star}, the planet's semi major axis D, as well as the eccentricity e of the orbit, and in turn the average stellar irradiation at the planet's location. Note that this definition of the HZ implies surface habitability and in turn allows remote detectability of life as we know it. Subsurface life that could exist on planets with very different surface temperatures is not considered here, because of the lack of remotely detectable atmospheric to assert habitability. A more eccentric orbit increases the annually averaged irradiation proportional to $(1 - e^2) 1/2$.

The inner edge of the HZ denotes the location where the entire water reservoir can be vaporized by runaway greenhouse conditions, followed by the photo-dissociation of water vapor and subsequent escape of free hydrogen Super-Earths stellar temperature (K) orbital distance (AU) into space. The outer boundary denotes the distance from the star where the maximum greenhouse effect fails to keep CO_2 from condensing permanently, leading to runaway glaciation. Note that at the limits of the HZ, the Bond albedo of a habitable planet is fully determined by its atmospheric composition and depends on the spectral distribution of the stellar irradiation. To simply estimate if an Earth-like planet as defined above is potentially habitable ($175\,K < T_{eq} < 270\,K$), one can approximate T_{eq} for Earth-like planets around different stars using the maximum albedo for rocky planet atmospheres, that varies depending on the planets cloud cover as well as host star.

Applying this definition to the first Kepler data, assuming circular orbits and albedo corresponding to 50 % cloud coverage (that is also consistent with the empirical "Venus"-limit of the HZ), leads to 27 Kepler planetary candidates with $175\,K < T_{eq} < 270\,K$ (see Fig. III.2.1).

Among those are 3 planetary candidates that have radii smaller than 2 Earth radii. Especially the potentially rocky Kepler planet candidates in multiple systems are extremely interesting objects because their mass could be determined using transit time variations to calculate a mean density and potentially confirm high density and rocky characteristics.

Low mass Main Sequence M dwarfs are the most abundant stars in the galaxy, representing about 75 % of the total stellar population. Many planets including potentially rocky planets within the HZ, like Gl 581 d, are thus likely to be found in the near future, providing excellent targets, that can be probed for atmospheric components, especially for hot planets with extended atmospheres. Fig. III.2.2 shows the position and borders of the HZ. The values for the rocky planet's in the Solar System as well as planets in the Gl 581 are shown. Several designs for future space missions that have the explicit purpose of detecting other Earth-like worlds as well as analyzing their characteristics, determining the composition of their atmospheres, and searching for signs of life are under study at ESA as well as at NASA. They also have the capacity to investigate the physical properties and composition of a broader diversity of planets, to understand the formation of planets and some even have the capability to interpret potential biosignatures.

A spectral fingerprint of an atmosphere

A planet is a very faint, small object close to a very bright and large object, its parent star. In the visible part of the spectrum we observe the starlight, reflected off the planet, in the IR we detect the planets own emitted flux. The Earth-Sun intensity ratio is about 10^7 in the thermal infrared (10 μm), and about 10^{10} in the visible (0.5 μm) (see Fig. III.2.3). Nevertheless the contrast ratio of hot Extrasolar Giant planets (EGP) to their parent stars as well as the contrast ratio of a planet to a smaller parent star is much more favorable, making Earth-like planets around small stars very interesting targets. Different strategies exist to characterize a planets atmosphere: direct detection that resolves the planet and star individually and transmission as well as secondary eclipse measurements that subtract the stellar light from a combined starplanet detection. The first imaged exoplanet candidates around young stars show the improvement in direct detection techniques that are designed to resolve the planet and collect its photons. This can currently be achieved for widely separated young objects and has already detected exoplanets.

Future telescopes will allow for direct detection in even closer orbits for closeby stars. In the next years ground-based as well as space missions will give us statistics on the number, size, period and orbital distance of planets, extending to terrestrial planets on the lower mass range end as a first step, while future space missions are designed to characterize their atmospheres. The atmosphere of a planet contains the detectable information to explore the planetary environment remotely. On Earth some atmospheric species exhibiting noticeable spectral features in the planets spectrum result directly or indirectly from biological activity: the main ones are O_2, O_3, CH_4, and N_2O (see Fig. III.2.3). CO_2 and H_2O are in addition important as greenhouse gases in a planets atmosphere and potential sources for high O_2 concentration from photosynthesis. Sagan analyzed a spectrum of the Earth taken by the Galileo probe in 1993, searching for signatures of life and concluded that the large amount of O_2 and the simultaneous presence of CH_4 traces are strongly suggestive of biology for a planet around a Sun-like star.

Fig. III.2.3 shows the detectable features in the planets reflection, emission and transmission spectrum using the Earth itself as a proxy for observations and model fits to data of spectra of the Earth. Our search for signs of life is based on the assumption that extraterrestrial life shares fundamental characteristics with life on Earth, in that it requires liquid water as a solvent and has a carbon-based chemistry. Life on the basis of a different chemistry is not considered here because the vast possible life-forms produce signatures in their atmosphere that are so far unknown. Therefore, we assume that extraterrestrial life is similar to life on Earth in its use of the same input and output gases, that it exists out of thermodynamic equilibrium. Biomarkers is used here to mean detectable species, or set of species, whose presence at significant abundance strongly suggests a biological origin (e.g. couple $CH_4 + O_2$, or $CH_4 + O_3$).

Bio-indicators are indicative of biological processes but can also be produced abiotically. It is their quantities, and detection along with other atmospheric species, in a certain context (for instance the properties of the star and the planet) that points toward a biological origin. It is relatively straightforward to remotely ascertain that Earth is a habitable planet, replete with oceans, a greenhouse atmosphere, global geochemical cycles, and life if one has data with arbitrarily high signal-to-noise and spatial and spectral resolution. The interpretation of observations of other planets with limited signal-to-noise ratio and spectral resolution as well as absolutely no spatial resolution, as envisioned for the first generation instruments, will be far more challenging and implies that we need to gather information on the planet environment to understand what we will see: After detection, we will focus on main properties of the planetary system, its orbital elements as well as the presence of an atmosphere using the light curve of the planet or/and a crude estimate of the planetary nature using very low-resolution information (3 or 4 channels).

Presently, radius measurements can only be performed when the planet transits in front of its parent star, by an accurate photometric technique. If the secondary eclipse of the transiting planet can be observed (when the planet

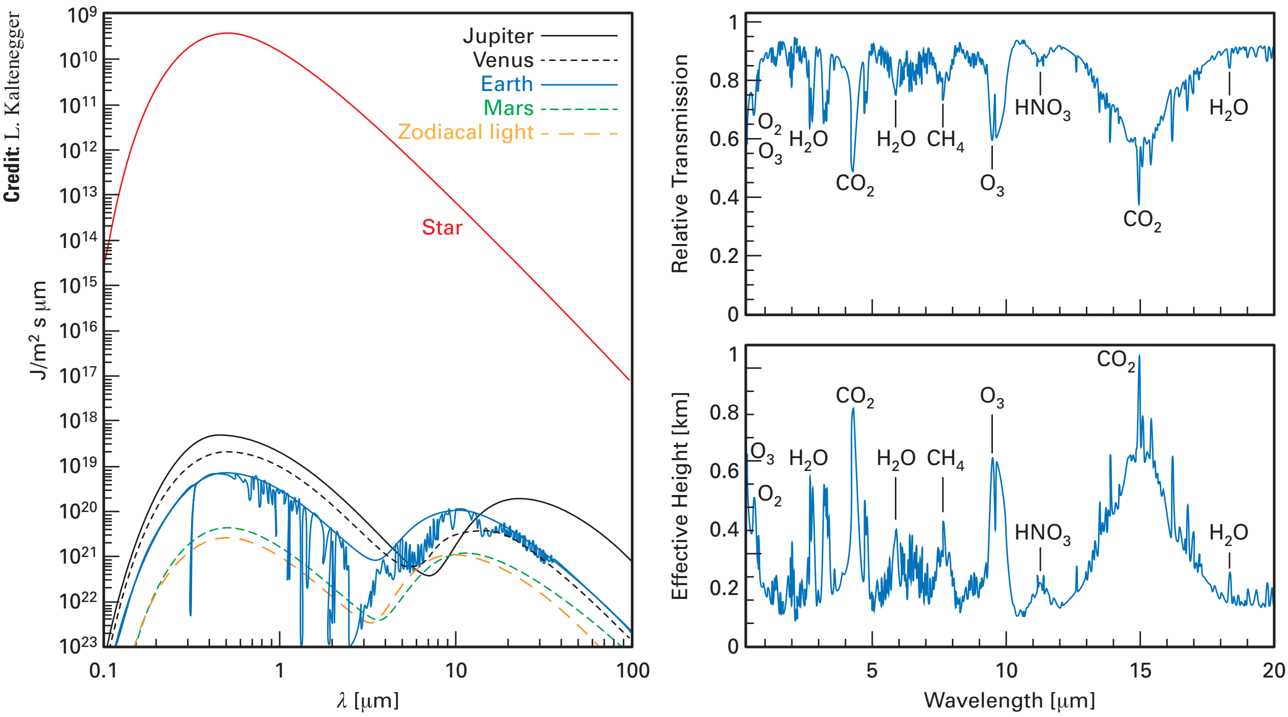


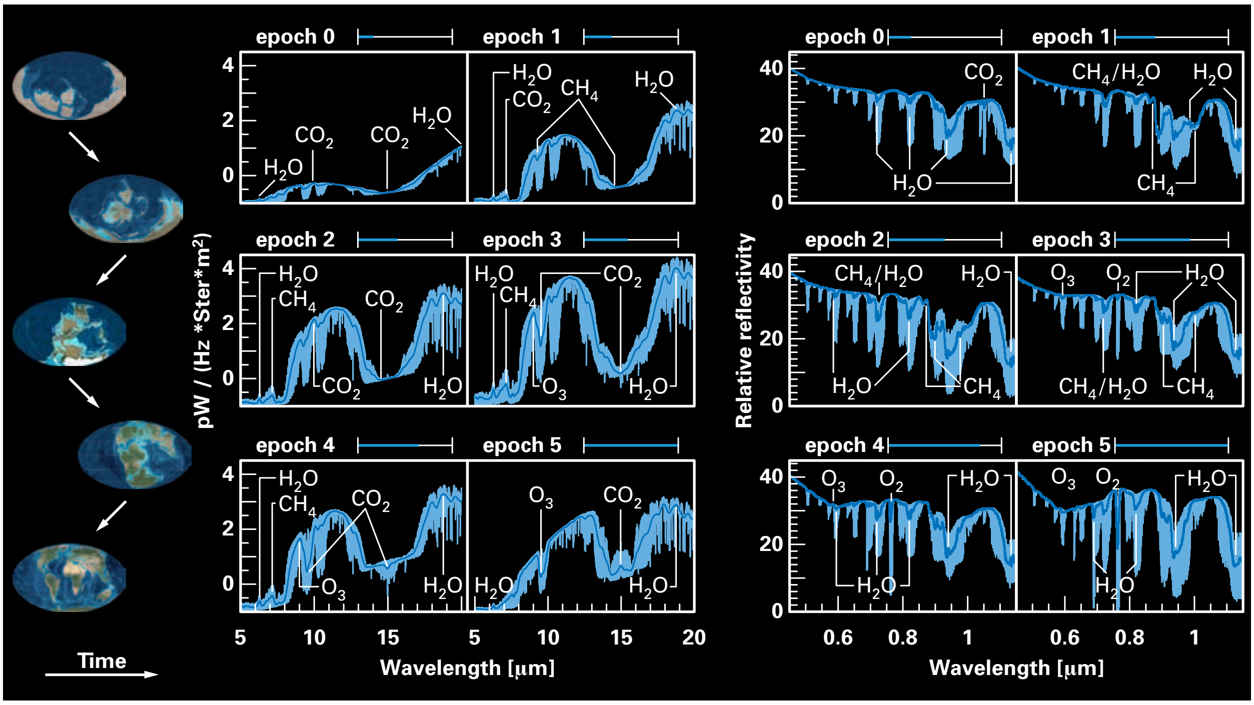
Fig. III.2.3: Model of our Solar System (*left*) (assumed here to be Black Bodies with Earth spectrum shown). Synthetic transmission spectra (*right*) of the Earth from UV to IR are shown. The intensity is given as a fraction of solar intensity as well as the relative height in the atmosphere. The atmospheric features are indicated.

passes behind the star), then the thermal emission of the planet can be measured, allowing the retrieval of mean brightness temperature thanks to the knowledge of the radius from the primary transit. If a non-transiting target is observed in both visible and IR ranges, the albedo can be estimated in the visible once the radius is inferred from the IR spectrum, and compared with one derived from the thermal emission only. Then a higher resolution spectrum will be used to identify the compounds of the planetary atmosphere, constrain the temperature and radius of the observed exoplanet. In that context, we can test if we have an abiotic explanation of all compounds seen in the atmosphere of such a planet. If we do not, we can work with the exciting biotic hypothesis. O_2, O_3, CH_4 are good biomarker candidates that can be detected by a low-resolution spectrograph (Resolution < 80). Note that the presence of biogenic gases such as O_2/O_3 + CH_4 may imply the presence of a massive and active biosphere, but their absence does not imply the absence of life. Life existed on Earth before the interplay between oxygenic photosynthesis and carbon cycling produced an oxygen-rich atmosphere (see Fig. III.2.4).

The coronagraph and occulter concepts detect the reflected light of a planet and operate in the visible and near infrared (0.5 – 1 µm) with a minimum resolution of 80. The interferometric systems suggested for future direct imaging missions operate in the mid-IR (6 – 20 µm) and observe the thermal emission emanating from the planet with a minimum resolution of 25. The viewing geometry results in different flux contribution of the overall detected signal from the bright and dark side, for the reflected light, and the planet's hot and cold regions for the emitted flux. Both spectral regions contain the signature of atmospheric gases that can be observed with low resolution and can indicate habitable conditions and, possibly, the presence of a biosphere: CO_2, H_2O, O_3, CH_4, and N_2O in the thermal infrared, and H_2O, O_3, O_2, CH_4 and CO_2 in the visible to near-infrared. The presence or absence of these spectral features (detected collectively) will indicate similarities or differences within the atmospheres of terrestrial planets, and its astrobiological potential.

Evolution of biomarkers over geological times on Earth

One crucial factor in interpreting planetary spectra is the point in the evolution of the atmosphere when its biomarkers and its habitability become detectable. The spectrum of the Earth has not been static throughout the past 4.5 billion years ago (Ga). This is due to the variations in the molecular abundances, the temperature structure, and the surface morphology over time. At about 2.3 Ga, oxygen and ozone became abundant, affecting the atmospheric absorption component of the spectrum. At about 0.44 Ga, an extensive land plant cover followed, generating a red chlorophyll edge in the reflection spectrum, that is potentially detectable with high SNR. The composition of the surface (especially in the



Credit: L. Kaltenegger

Fig. III.2.4: The visible to near-IR (*left*) and mid IR (*right*) spectral features on an Earth-like planet change considerably over its evolution from a CO_2 rich (epoch 0) to a CO_2/CH_4-rich atmosphere (epoch 3) to a present-day atmosphere (epoch 5). The bold lines show spectral resolution of 80 and 25 comparable to the proposed visible TPF-C/New World Observer and Darwin/TPF-I mission concept, respectively.

visible), the atmospheric composition, and temperature-pressure profile can all have a significant influence on the detectabilty of a signal.

Fig. III.2.4 shows theoretical visible and mid-infrared spectra of the Earth over the main six epochs during its geological evolution. The epochs are chosen to represent major evolutionary stages of the Earth, and life on Earth. If an extrasolar planet is found with a corresponding spectrum, we can use the stages of evolution of our planet to characterizing it, in terms of habitability and the degree to which it shows signs of life, assuming similar evolution time scales. Furthermore we can learn about the evolution of our own planets atmosphere and possible the emergence of life by observing exoplanets in different stages of their evolution. Earth's atmosphere has experienced dramatic evolution over 4.5 billion years, and other planets may exhibit similar or greater evolution, and at different rates. Fig.III.2.4 shows epochs that reflect signifcant changes in the chemical composition of the atmosphere. The ozone/oxygen absorption features could have been used to indicate the presence of biological activity on Earth in combination with a reducing gas like CH_4 anytime during the past 50 % of the age of the Solar System. Different signatures in the atmosphere are clearly detectable over Earths evolution and observable with low resolution. Such spectra will be used as part of a big grid to characterize any exoplanets found and influences the design requirements for a spectrometer to detect habitable planets, a grid different international groups are working on. Other geochemical cycles as well as volcanic events can also leave observable features in a planets atmosphere that can potentially be detectable.

Summary

Spectroscopy of the atmosphere of extrasolar planets allows to remotely explore a planets environment, distinguishing Mini-Neptunes from rocky Super-Earths, exploring atmospheric compositions as well as searching for indications for habitability. Any information we collect on habitability is only important in a context that allows us to interpret, what we find. To search for signs of life we need to understand how the observed atmosphere physically and chemically works. Knowledge of the temperature and planetary radius is crucial for the general understanding of the physical and chemical processes occurring on the planet. These parameters as well as an indication of habitability can be determined with low resolution spectroscopy and low photon flux, as assumed for first generation space missions. The combination of spectral information in the visible (starlight reflected of the planet) as well as in the mid-IR (planet's thermal emission) allows a confirmation of atmospheric species, a more detailed characterization of individual planets but also to explore a wide domain of planet diversity. Being able to measure the outgoing shortwave and longwave radiation as well as their variations along the orbit, to determine the albedo and identify greenhouse gases, would in combination allow us to explore the climate system at work on the observed worlds, as well as probe planets similar to our own for habitable conditions.

Lisa Kaltenegger, Yan Betremieux, Siddharth Hedge, Yamila Miguel, Andreas Zsom

III.3 The Milky Way in a cosmological context

Our own galaxy, the Milky Way, is a typical spiral galaxy, representative of the most common type of massive galaxies in the Universe. We can use the Milky as an ideal and unique laboratory to study systematically all the physical processes that shape a galaxy, at a detail that is impossible to attain in other galaxies.

Ultimately, our understanding of the formation, evolution and structure of the Milky Way has to be considered in the cosmological context of hierarchical structure formation in a Universe dominated by dark matter and dark energy. In this standard paradigm, disk galaxies like our Milky Way are believed to form out of cold gas that settles in centrifugal equilibrium in the center of a dark matter halo that continues to accrete new material. This newly accreted material consists in part of virialized dark matter haloes of different masses and sizes, each of which may contain a stellar component in its central region. In addition, a sizable amount of material is accreted smoothly, either through filamentary "cold flows", or by passing through spherically symmetric accretion shocks. Depending on the subsequent dynamical evolution, the accreted subhaloes and their associated satellite galaxies may either be disrupted due to tidal forces, merge with the central disk galaxy, or survive to the present day as distinct objects orbiting the halo that surrounds the stellar disk. Tidal stripping (and disruption) of satellite galaxies gives rise to a diffuse stellar halo as well as to tidal streams. Stellar tidal streams have indeed been identified in the haloes of the Milky Way and the Andromeda galaxy, and provide us with a fossil record of the hierarchical formation history.

Merging satellites may help to form a thick disk component, both by dynamically heating part of the existing disk, and by directly adding their stellar content. Thus, merging processes, which are an integral ingredient of hierarchical structure formation, are expected to contribute in shaping the Milky Way disk.

Also, cold accretion streams may affect the angular momentum of the disk during its formation, particularly at high redshift. It is clear, then, that within this standard framework, the formation, evolution and structure of the stellar halo, the thin/thick disk components are tightly intertwined with the satellite galaxies of the Milky Way.

In principal, the standard cosmological model specifies the initial conditions for cosmic structure formation, and hence for the formation of the Milky Way, exactly. Evolving this initial state forward in time and connecting the outcome to observations of the Milky Way is therefore an extremely powerful approach for testing galaxy formation theory. However, the set of partial differential equations that describe the evolution are much too complicated to be solved analytically in their full geometrical complexity, even for significantly simplified physics. But the computational challenge can be addressed through direct numerical simulations.

Scientists at the MPIA are bringing fundamental contributions to this field, in collaboration with other international Institutions and Universities.

Numerical modelling of Galaxy Formation

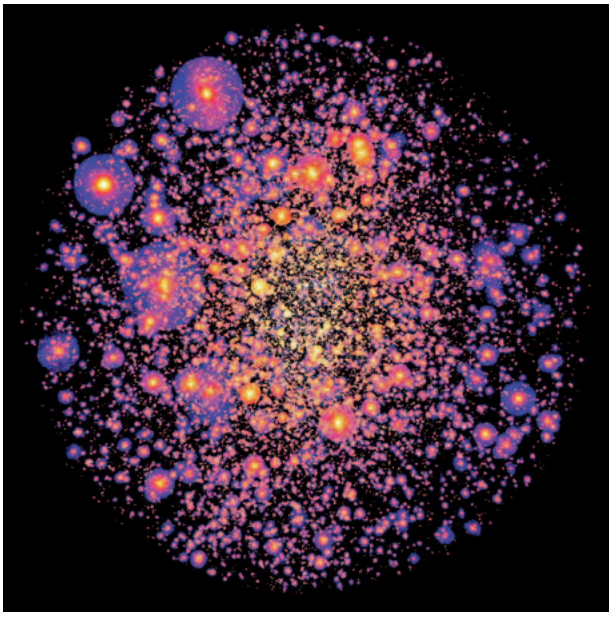
N-body/gas-dynamical simulations are one of the primary tools to model galaxy formation in a cosmological context. They are necessary to follow the non-linear evolution of the internal structure of galaxies as well as the complex interplay between baryonic cooling and feedback. Existing cosmological simulations of the standard cosmological model have reached a high degree of sophistication and resolution as far as the dark matter is concerned.

The best resolved collisionless simulations of the formation of the Milky Way reach mass resolutions of about 1000 solar masses, representing the virialized region with more than a billion dark matter particles and resolving up to $\sim$ 300 000 dark matter satellites (see Fig. III.3.1).

However, simulations that also account for baryonic physics have thus far been much less successful. In fact, they have generally experienced significant problems to account for the morphology of the Milky Way disk, the paucity of luminous satellites, the baryonic content of the Milky Way's halo, or the chemical properties of the Milky Way's stellar populations.

For example, early work reported a catastrophic loss of angular momentum in the baryonic component of simulated galaxies, leading to the formation of galaxies dominated by a central concentration of cold baryons. Only the most recent gas dynamical simulations have achieved a spatial resolution sufficient to resolve the disk scale lengths. It is generally hoped that a more realistic treatment of processes such as reionization and supernova feedback will result in more realistic disk galaxies.

Another problem for galaxy formation in a Cold Dark Matter cosmology is that dark matter-only simulations predict abundances of dark matter subhaloes that are orders of magnitude larger than the abundances of observed luminous satellite galaxies in the haloes of the Milky Way or the Andromeda galaxy. It is believed that feedback processes associated with star formation make galaxy formation extremely inefficient in low mass haloes, and may even completely prevent galaxy forma-



Credit: A. Macciò

Fig. III.3.1.: Predicted Dark Matter distribution in collapsed structures (i.e. satellites) in the halo of a Milky Way like galaxy. Brighter colors indicate higher density, the central core of the dark matter halo is not shown.

tion in haloes below a given mass. This problem can hence only be solved with a more realistic treatment of reionization and/or supernova feedback. So far, the satellite population has almost exclusively been studied with semi-analytic techniques, due to the computational expense of full hydrodynamic simulations with the necessary resolution. In these approaches, a strong influence of photo-heating is invoked to reduce the star formation efficiency in dwarfs.

Dynamical friction plays an important role in the orbital evolution of dwarf galaxies and also in the position and shape of tidal streams. Semi-analytic investigations of satellite orbits and streams, combined with comparisons to N-body simulations, have been successfully used to constrain the allowed parameter range.

In the next paragraph we summarize recent achievements from MPIA scientists in reproducing the properties of our Galaxy in a cosmological framework.

We show how stellar streams in our own Galaxy can be used to constrain the nature of the elusive Dark Matter component. We conclude with presenting some future directions in this exciting research field.

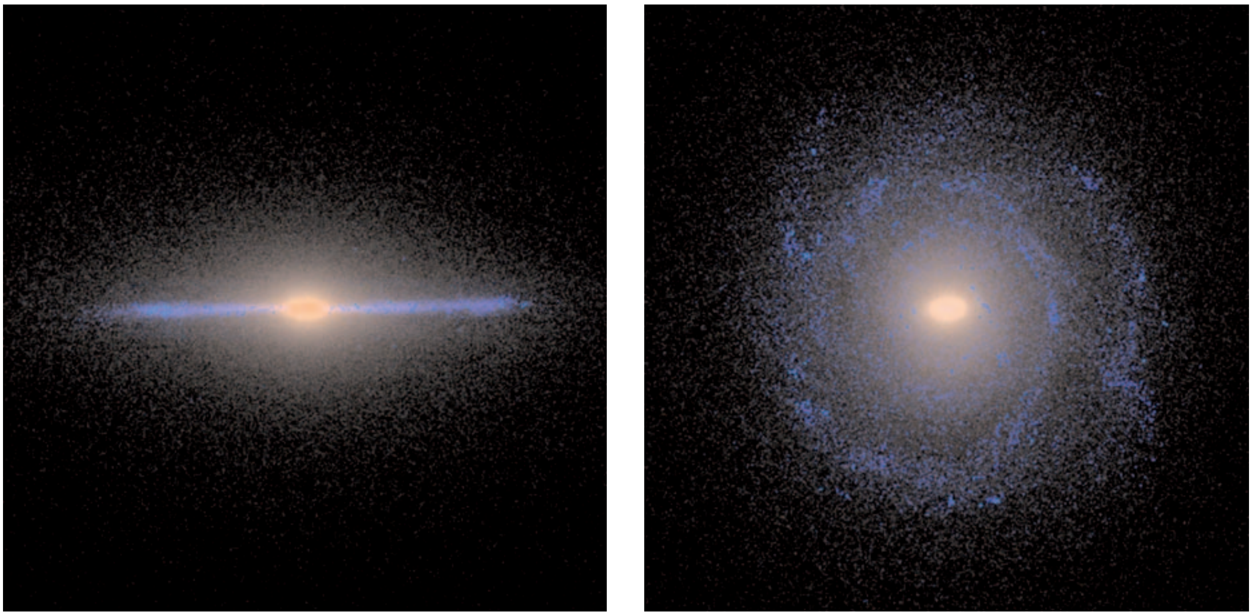
Formation of Disk Galaxies

Several studies of galaxies in a cosmological context have generated individual objects that are similar to the observed local galaxies. These require high resolution and large computational resources in order for several important properties of the simulations to converge, including the galactic structure, motions and Star Formation History (SFH). In the last years scientists at the MPIA (Greg Stinson and Andrea Maccio) have been working on performing and improving high resolution cosmological simulations. One of the outcomes of this effort has been the creation of a large data base of state of the art simulated disc galaxies that can now be compared with observations.

These simulations have been created using the Gasoline code, originally developed at the University of Washington by J. Wadsley and collaborators, and then extended by several code developers, including G. Stinson. The code is based on the Smoothed Particle Hydrodynamics (SPH) technique and solves the equation for gravity (dark matter, gas and stars) and for hydrodynamics (only gas). The code includes radiative cooling from both primordial and metal enriched gas, a uniform ionizing ultraviolet background, and a novel parameterization of star formation, and feedback from Supernovae. This star formation and feedback treatment was one of the keys to the success of Governato et al. (2007) in producing realistic spiral galaxies in a cosmological simulation and the success of Brooks et al. (2007) in matching the observed mass metallicity relationship.

These simulations are quite challenging from the computational point of view. They aim at following the evolution of a galaxy like the Milky Way along the entire life of the Universe (13.7 billions of years), with accurate spatial and mass resolution in order to make a detailed comparison with observational data. This requirement for high resolution usually implies a spatial resolution of ~50 pc, and at least 100 000 stellar mass elements in the galactic disk. Such a simulation can take up to a couple of months on a modern parallel supercomputer using 50 to 100 processors. Another important point to keep in mind is that real galaxies, when observed in detail, present quite a variety of properties. This implies that a single simulated galaxy, although performed with exquisite resolution, will never be able to capture this diversity in galaxies properties. A statistical significant ensemble of simulated objects is then needed and required. This has been one of the goals of a large simulation campaign, started by G. Stinson in 2010 and carried on at the MPIA, using the institute's supercomputer Theo at the Rechenzentrum in Garching. So far a portfolio of 20 galaxies has been produced and it will be substantially expanded in the incoming year.

The most intuitive way to compare simulations with observations is through mock images of the simulations. Such images can be created by assigning stellar population models to each star particle to determine the color and luminosity each star particle should contribute to an image. Additionally, dust can modulate the image with extinction and scattering. Sunrise (Jonsson 2006) is a Monte Carlo ray tracing program that produces simulated images assuming that dust exists in metal rich gas. Fig. III.3.2 shows images 50 kpc on a side that include scattering and absorption using Sunrise. The galaxy is



Credit: (beide Bilder) A. Macciò

Fig. III.3.2.: Edge-on (*left*) and face-on (*right*) mock composite (g, r, and i band) of one simulated galaxy using the Monte Carlo radiative transfer program SUNRISE. Each image is a two-dimensional projection of a box 50 kpc on a side.

aligned so that the total angular momentum of the gas inside 1 kpc is pointed upwards and towards the reader in the left and right panel respectively. One can see a thin disk of young, blue stars is surrounded by a halo of old, red stars. The simulated galaxies have colors and magnitudes that compare well with a sample of isolated galaxies from the Sloan Digital Sky Survey (SDSS), and in particular separate into the well known red sequence and blue cloud.

On the other hand they still present too many "old" stars and a slightly too concentrated central core. Stinson & Macciò together with other scientists at MPIA are now working on an improved version of the simulation code, that combines higher numerical resolution with a new model of radiation pressure feedback. Tests of this new simulation scheme have produced very promising results that are expected to strongly improve our understanding of disk galaxy formation, including the formation of our own Milky Way.

Satellites around the Milky Way

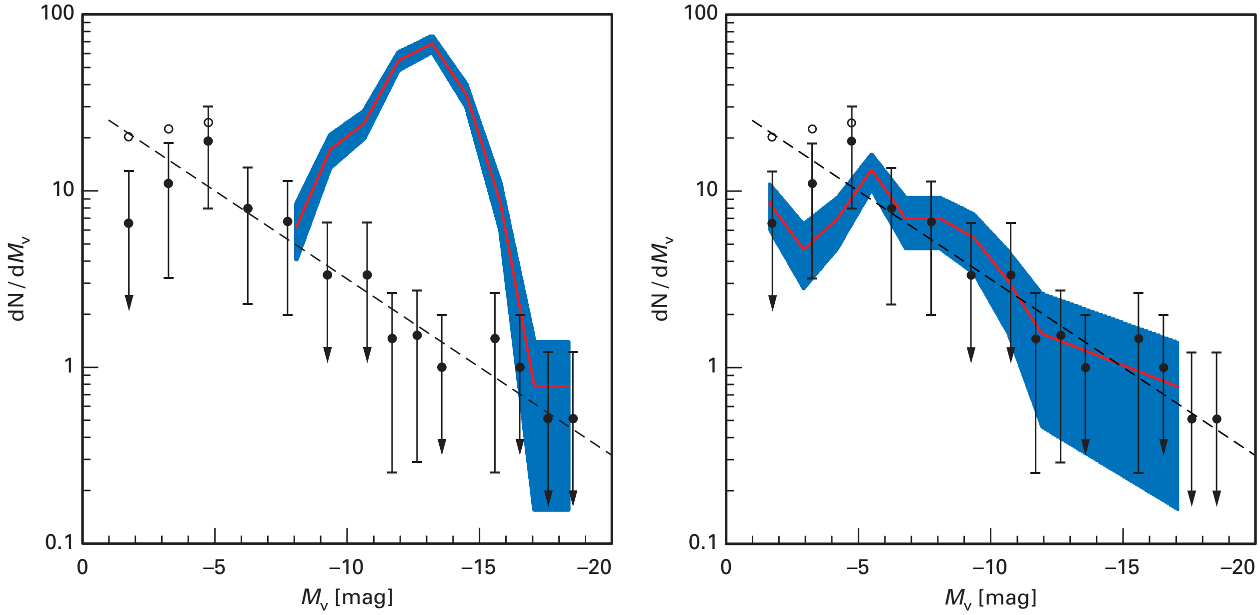
Predictions of the number density of satellites around our Galaxy have long been considered one of the major problems for the otherwise quite successful ΛCDM paradigm. About a decade ago, N-body simulations attained sufficient dynamic range to reveal that in CDM models, all haloes should contain a large number of embedded sub-haloes that survive the collapse. Although the predicted number of substructures was in reasonable agreement with observed luminosity functions in cluster sized haloes, in Milky Way sized haloes the number of predicted sub-haloes exceeded the number of observed satellites by at least an order of magnitude.

Many authors have pointed out that accretion of gas into low-mass haloes and subsequent star formation is inefficient in the presence of a strong photoionizing background, as this background radiation raises the entropy of the gas, preventing it from accreting on to small dark matter haloes and lengthening the cooling time of the accreted gas. It was also pointed out that tidal stripping and heating of satellites orbiting in the potential of the larger galaxy could cause dramatic mass loss.

In recent years the Sloan Digital Sky Survey (SDSS) has changed our view of the Milky Way and its environment. The SDSS has made it possible to carry out a systematic survey of satellite galaxies, which are detectable through their resolved stellar populations down to extremely low surface brightness. As a result the number of known dwarf (spheroidals) galaxies has doubled in the recent past.

These new observations have made it possible to probe the faint end of the Luminosity Function of Milky Way satellites, down to luminosities as faint as few hundred solar luminosities. Moreover, the homogeneous sky coverage of the SDSS enables a robust determination of the detection limits for faint satellites. A study lead by Sergey Koposov at MPIA has provided the first determination of the volume corrected Milky Way satellite Luminosity Function down to these extremely faint limits.

In light of the discovery of the new ultra-faint dwarf population and the improvements in the numerical modelling of galaxy formation, Andrea Maccio' and collaborators have extensively revised the issue of whether the basic properties of satellite galaxies around the Milky



Credit: A. Macciò, S. Koposov et al., 2008

Fig. III.3.3: The Milky Way satellite Luminosity Function predicted by combining N-body simulations with semi analytical models. *Left:* model without baryonic feedback. *Right:* model with baryonic feedback. In both panels the median of the satellite distribution is shown by the solid (*red*) line, while the shaded area represents the 1σ Poisson scatter around the mean. Observational data are shown by the black symbols.

Way, such as luminosity, number density radial distribution and central mass, can be reproduced within the current cosmological model. They also asked the question what processes might plausibly give rise to this population of extremely low-luminosity galaxies. The method employed in these series of studies is based on the coupling of dissipationless simulations of pure dark matter with sophisticated semi analytic models (SAMS) able to predict the observable properties of galaxies that inhabit the dark matter haloes.

Pure gravity simulations (often called N-body simulations) describe the hierarchical assembly of the dark matter component of the Milky Way halo. They can achieve a higher resolution of hydrodynamical simulations (like the one described above), allowing in this way a better description of dynamical processes and the possibility of exploring very low satellite masses, like the faintest satellites observed in the SDSS. Unfortunately, these simulations only provide information on the distribution of Dark Matter, which is not directly visible.

Semi analytical models, developed by former MPIA staff and postdocs including X. Kang, R. Somerville and F. Fontanot, are able to accurately parameterize the main physical process acting on the baryonic component, such as atomic cooling, cosmic reionization, star formation, Supernovae feedback, metal production and dust attenuation. By following the dynamical evolution of satellites (as predicted by the N-body simulation), they are able to establish for each (dark) object a stellar mass, gaseous mass, luminosity and many other properties that can be directly compared with observations.

The results obtained combining these two methods are summarized in Fig. III.3.3, where the predicted Luminosity Function (red line, with grey shaded showing the 1σ confidence level) is compared with the observational data (black points with error bars). The left panel shows the results in the absence of baryonic processes like photoionization, SN feedback or stellar stripping. In this case the predicted satellite Luminosity Function shows a peak at around $M_V \sim -14$ mag (where M_V is the magnitude in the V band) and a sharp drop-off at $M_V > -10$ mag, with essentially no satellites fainter than $M_V > -8$ mag predicted. In clear contrast with observations, that extend to luminosities as faint as $M_V = 2$ mag. This shows that in the absence of some kind of feedback or suppression mechanism, these satellites rapidly cool all of the available baryons (gas) and convert them into stars.

The right panel shows instead the Luminosity Function obtained taking into account the complicated network of physical processes involving baryons. Photoionization due to a cosmic reionizing back-ground and Supernova feedback work together in order to reshape this highly peaked Luminosity Function into the near-power law down to $M_V \sim -3$ mag, in very good agreement with the recent SDSS observations. Photoionization suppresses then fall of hot gas into low-mass dark matter haloes, reducing the supply of baryons that are available for cooling and star formation, while SN feedback reheats cold gas and expels it from small haloes, again suppressing the efficiency of star formation. Comparison with observations is not limited to the Luminosity Function, but extends to other dwarf galaxy properties like their sizes. In Fig. III.3.4, the size luminosity relation is shown for observed galaxies (the blue line, obtained by Crystal Brasseur and Nicolas Martin at MPIA) and for simulated objects (red and green symbols). Also in this case there is a very good agreement between cosmological based predictions and observations.

In summary, these results show that not only is there no longer a "missing satellite problem", but that well-known and well-motivated astrophysical processes working within the ΛCDM framework naturally predict the form of the observed MW satellite Luminosity Function over six orders of magnitude in luminosity. These studies confirm once more the robustness of the ΛCDM paradigm and the importance of the Milky Way environment as test bed for cosmological theoretical models.

Work in progress: Hunting for the dark

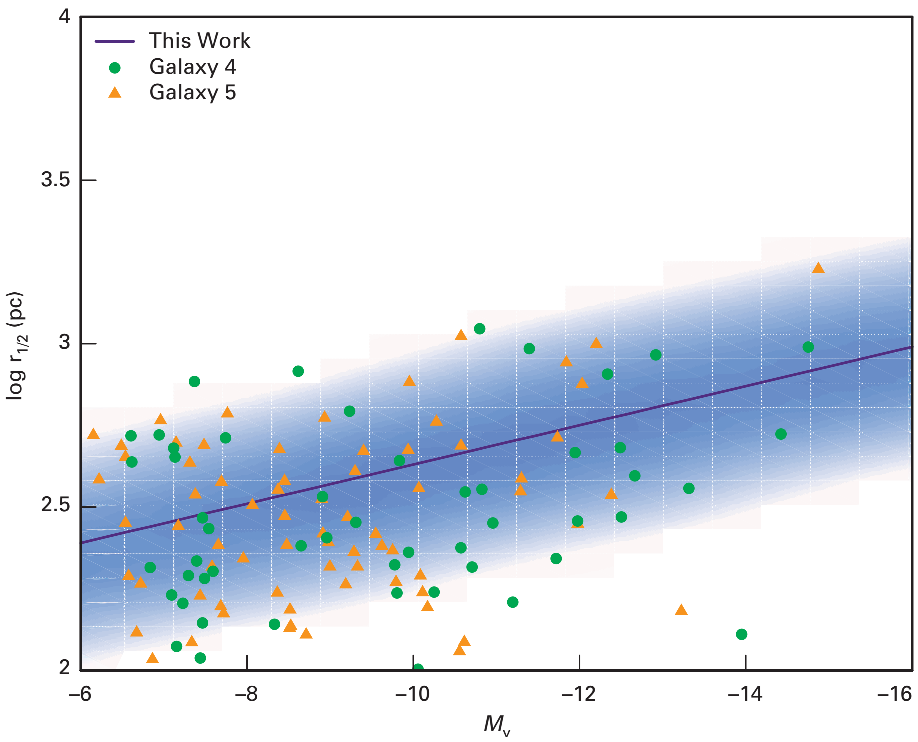
If the Cold Dark Matter model is correct we expect hundreds of dark satellites (i.e. satellites made only of dark matter, hosting no visible galaxy) orbiting around our Galaxy, as shown in Fig. III.3.1. Those satellites can only be detected through their gravitational effects. The detection of such a population of dark objects is one of the last remaining major challenges for the ΛCDM paradigm.

Along with the discovery of new satellite galaxies, SDSS has also uncovered a multitude of stellar structures in the Milky Way halo from disrupting globular clusters or satellite galaxies. In many cases, the debris is dynamically cold and distributed narrowly in space. Such cold stellar streams should be sensitive probes of the gravitational potential. On global scales, they can be used to constrain the radial profile, shape, and orientation of the Milky Way's triaxial dark matter halo. The presence of dark matter subhalos would add asymmetries to the global potential at smaller scales which will perturb these cold streams or even destroy them. Debris from the destruction of a 10^6 $M_\odot$ globular cluster should be affected by heating due to repeated close encounters of subhalos and this effect could be detectable with future astrometric surveys like GAIA.

For these reasons a pilot study in this direction is currently been carried out at the MPIA. Built on previous work this study aims at addressing the effects of individual encounters, the distinct signatures of subhalos in different mass decades, the integrated influences of subhalo encounters, and eventually comparing numerical work with observational data.

The set up is as follows: a database of hundred stellar streams have been created, these streams are in equilibrium within the gravitational potential consisting of a dark matter halo and stellar disc. These streams are then evolved in time for 3 billion years. In the absence of perturbing objects (e.g. low mass dark-matter-only satellites) streams do not deviate from the original orbit and they conserve their shape as illustrated in the left panel of Fig. III.3.5.

Fig. III.3.4: The solid purple line and the shaded region correspond to the observed Luminosity-Size relation for the combined sample of Milky Way and Andromeda satellites. The green and yellow points correspond to predictions from cosmological simulations.



Credit: A. Macciò

Credit: (beide Bilder) A. Macciò

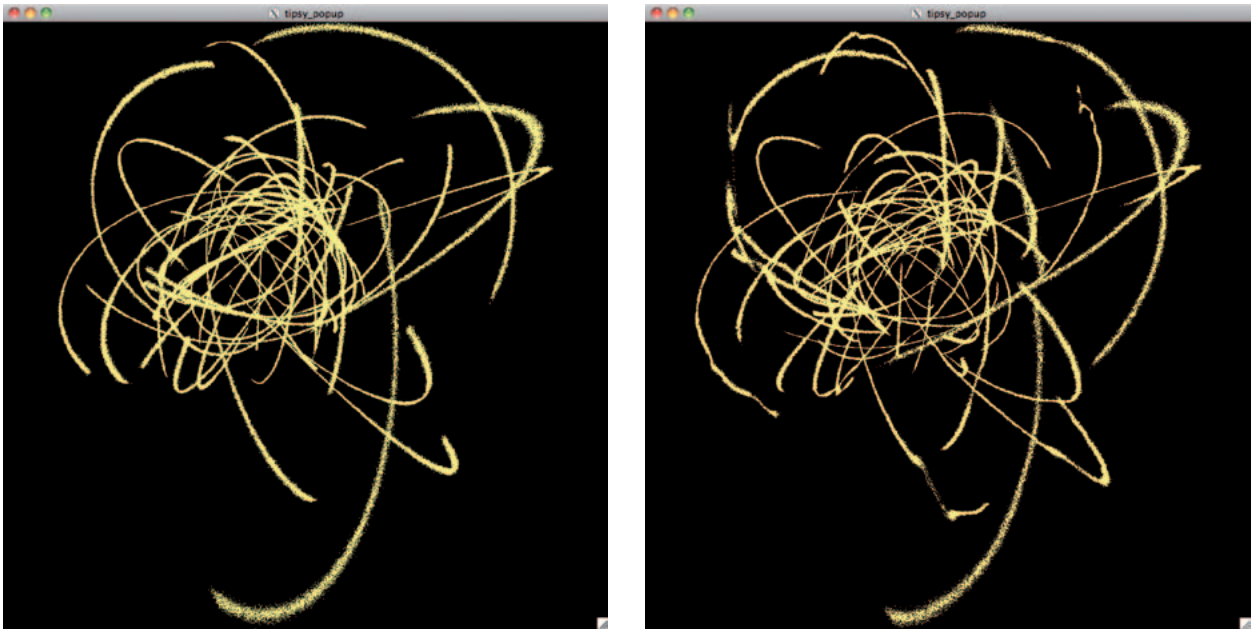


Fig. III.3.5: Distribution of stars in 100 simulated stellar streams in the inner 100 kpc from the galactic center. The left panel is for the case with no perturbers, while the right one includes the effects of a population of dark satellites, as predicted by the current cosmological model.

The situation changes quite strongly, when the distribution of dark matter satellites as predicted by the Cold Dark Matter model (Fig. III.3.1) is added. The effects of this large family of perturbing objects are visible in the right panel of Fig. III.3.5, where many streams show different degrees of perturbation: kinks, holes, bifurcations etc. On the other hand there are also streams that are similar to their "partner stream" in the non perturbed case.

This preliminary work shows that: 1) The mere existence of cold stellar streams does not imply the absence of dark satellites. Dynamically cold streams can survive for many billion years even when bombarded by subhalos. 2) A consistent fraction of stellar streams in the Milky Way halo, should contain the imprint of past direct impacts from subhalos in the form of gaps in their surface density and discontinuities in velocities. The frequency and scale of the gaps depends on the properties of the stream itself and on the mass spectrum of subhalos. This latter dependency can be used to constrain the "temperature" of the dark matter (Cold vs Warm) and hence the nature of the dark matter itself. Planned astrometric surveys like Gaia, will provide a comprehensive analysis of stellar streams in the Milky Way, which can be compared with predictions from simulations as above.

The Milky Way is a keystone for understanding galaxy formation. Exploiting its scientific potential, as an astrophysical laboratory, requires a varied set of tools at the forefront of modern cosmological research: mining large surveys, observations with the largest telescopes, massive parallel supercomputer simulations including hydrodynamics, detailed theoretical models for galaxy dynamics and galaxy formation and advanced statistical methods to analyze such an amount of observed and simulated data. Luckily, the Galaxies and Cosmology group at the MPIA hosts diverse groups of researchers and is involved in projects spanning all of these areas.

Andrea Macciò, Crystal Brasseur, Nicolas Martin

III.4 Molecular Gas and Dust in High Redshift Objects

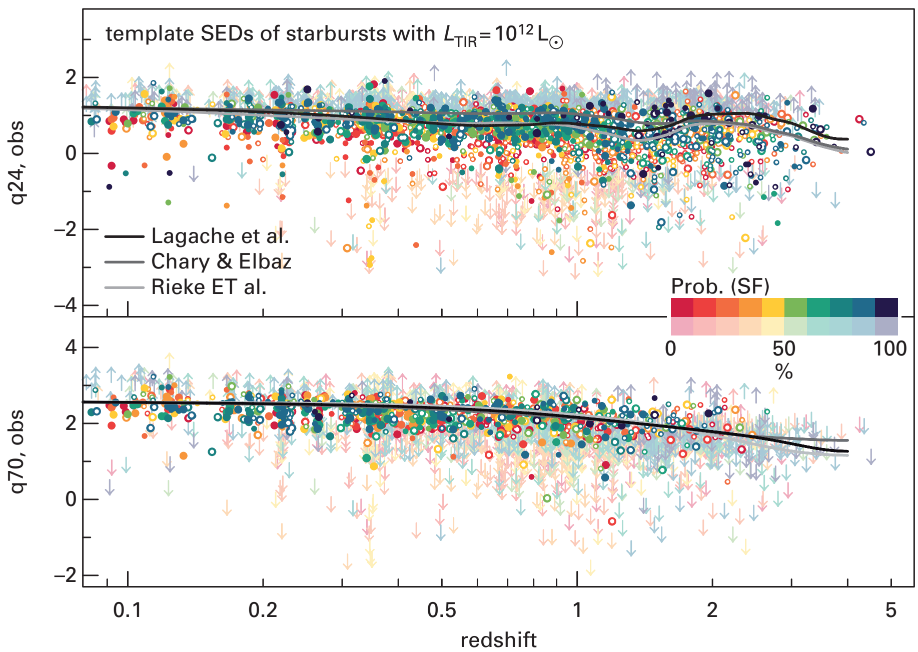
The molecular gas in galaxies is the material out of which stars form, and the emission from these stars, in turn, heats the interstellar molecular gas and dust. While the stellar population is typically studied in the optical and near–infrared regime, the molecular gas and dust can be traced through spectral lines in the millimeter wavelength range or in the (sub-)millimeter and far-infrared continuum. Wavelengths much longer than infrared thus provide important diagnostic tools for characterizing the molecular gas and dust reservoirs in distant galaxies, which, in turn, give valuable clues on the ability of these galaxies to form stars. A key objective is therefore to study how the star formation ability and molecular gas reservoirs of galaxies evolve with cosmic time.

Star formation can also be observed in the radio bands at wavelengths longer than 1 cm. The most massive stars $M_{\rm star} > 5\,M_\odot$ are short-lived and explode in powerful supernova events soon after they are born. The shockwaves of the explosion ripple through the interstellar medium and displace its constituent particles. If these particles are electrically charged, their movement through the magnetic field (which presumably exists in all galaxies) generates so-called 'synchrotron' radio emission. Hence the optical, (near-)infrared, (sub-)millimeter and radio portions of the electromagnetic spectrum of a star-forming galaxy all provide critical information on the current star formation activity and the 'fuel' for future star formation episodes.

As a reference, the number of new stars formed in our own galaxy, the Milky Way, amounts to the equivalent of roughly one solar mass (1 $M_\odot$) per year. This is a typical value for the bulk of normal star forming galaxies in the present cosmic epoch, ~ 13.5 billion years (Gyr) after the Big Bang. Some exceptional galaxies, however, show much higher levels of star formation activity, at times exceeding rates of ~1000 $M_\odot$ yr^{-1}. While some of these so-called 'starburst' galaxies can be found in the local universe, the more extreme versions are typically observed at earlier cosmic times when the universe was less than half of its present age.

Because the spectrum of an object shifts to longer wavelengths with redshift, the peak of the star formation-powered dust emission and related spectral lines in the rest frame FIR of distant starbursts can be observed locally in the (sub-) millimeter regime. This is why the

Fig. III.4.1: Observed (i.e. not K-corrected) monochromatic IR/radio flux density ratios q24, obs (*top*) and q70, obs (*bottom*) as a function of redshift. The measurements are colored according to their probability of being a star forming system (dark/light color coding is used for sources with spectroscopic/photometric redshifts, respectively). The black and grey tracks show the IR/radio flux ratios of model starbursts (cf. legend along upper edge). The tracks closely follow the data, suggesting no evolution in the infrared-radio relation out to at least $z \sim 1.4$.



Credit: J. Hodge

(sub-)millimeter is particularly important for detailed studies of starburst galaxies at high redshift. The massive young stars that form in such starbursts emit copious amounts of radiation, influencing the gas and dust in and between the galaxies. This allows researchers to study both the gas and dust that have been subjected to the intense radiation of the newborn stars, as well as the properties of the starburst itself, tracing the evolution of these properties with cosmic time.

In the following, we describe a number of recent studies at MPIA that aim to understand the relationship between the molecular gas, dust emission, and star formation in high-redshift objects as a function of lookback time. Most of these studies capitalize on long – wavelength observing facilities such as the (E)VLA, the Iram millimetre facilities, and the Spitzer and Herschel space telescopes.

Evolution of the Infrared-Radio Relation

In the local universe, a correlation exists between the infrared and radio energy emitted by star forming galaxies. This so-called 'IR-radio correlation' is one of the best-defined relations in extragalactic astrophysics. Since the IR-radio relation provides insight into the physics of the interstellar medium and star formation, the question of whether or not it still holds at high redshift (i.e. large cosmic lookback times) has attracted much interest. Answering this question is also necessary in order to determine whether radio emission can be used as a star formation tracer in distant galaxies.

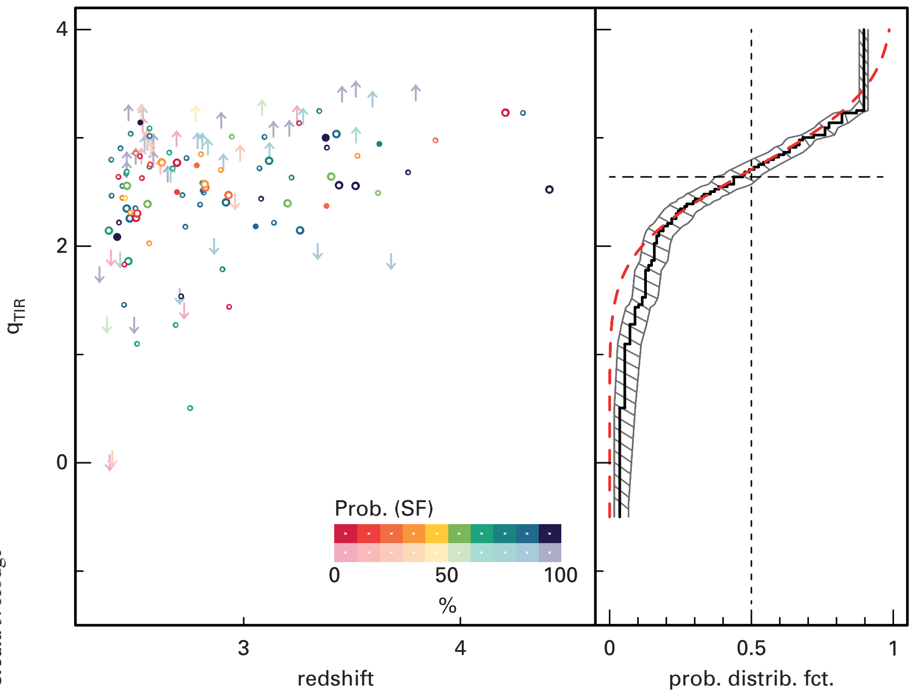
Intermediate Redshift ($z < 1.4$) Starbursts and AGN

MPIA astronomers have set out to measure the evolution of the IR – radio relation to high redshift by studying galaxies in the 2 deg^2 Cosmos field. This large and diverse sample of ~ 50 000 band-matched radio, IR and optical sources represents the largest sample so far used for an evolutionary study of this kind. A robust statistical analysis provides firm support for previous findings that the IR-radio relation remains remarkably unchanged out to at least $z \sim 1.4$ (see Fig. III.4.1).

The IR/Radio Properties of High-Redshift Galaxies

At even higher redshifts, the Cosmos survey provides ~ 150 sources for a similar study at $z > 2.5$. This currently represents the largest sample of high-z sources for which it is possible to study the IR-radio relation via a large fraction of direct detections rather than flux limits. The average IR/radio flux ratios of these sources – the most distant of which are detected when the universe was only ~ 1.4 Gyr old – are very similar to those in the local universe. This is a remarkable finding, since the

Fig. III.4.2: At the highest redshifts sampled by the Cosmos VLA and Spitzer surveys, the median value of the logarithmic IR/radio flux ratio qTIR is still unchanged in comparison to the locally measured average. *Left:* measured values of qTIR in the range $2.5 < z < 5$. *Right:* Cumulative distribution function of measured IR/radio flux ratios (*black curve*) with best-fitting Gaussian (*red dashes*) and local average (*black dashes*) indicated.



Credit: J. Hodge

synchrotron emission from these highly infrared-luminous sources is expected to be strongly suppressed due to the inverse Compton scattering of their cosmic ray particles off the intense microwave background radiation from the Big Bang.

Extreme Starbursts Less than 1.5 Billion Years After the Big Bang: Cosmic Structure Formation at Work in the Very Young Universe

Extreme starbursts play an important role in the young universe by providing observational evidence for cosmic structure formation. While at sufficiently large scales the matter in the universe is homogeneously distributed, on smaller scales of several million parsecs local galaxies are typically clustered and gravitationally bound, following the dark matter filaments of the cosmic web. Observationally, our understanding of this filamentary development over time is still so poorly constrained that extensive cosmological computer simulations provide the basis of our current knowledge of cosmic structure formation. These simulations predict galaxy overdensities (proto-clusters) to exist already at very early cosmic epochs. Even these proto-clusters, however, which are thought to develop into the most massive galaxy clusters observed to date, have generally been challenging to find.

The tremendous star formation rates of several hundreds of solar masses per year in high-redshift starbursts imply that the huge reservoirs of molecular gas in these galaxies would be depleted in as little as ~ 100 Myr. In this scenario, they would have built up a total stellar mass consistent with the most massive elliptical (and no longer star forming) galaxies observed in the local universe. It has long been speculated that such massive starbursts already exist at even earlier cosmic times in the redshift range $z > 4$, only $> \sim 1.5$ Gyr after the Big Bang. If such objects can be detected in sufficient numbers and with properties matching those of the $z \sim 2$ starbursts, then these ancient starbursts could be the progenitors of the earliest massive elliptical galaxies that are already observed at $z > 2$.

The major obstacle in revealing them among known (sub-)mm sources has been the poor angular resolution of the single-dish telescopes that are typically used for the majority of the (sub-)mm observations. Although higher resolution interferometric radio imaging can be used as an alternative to pinpoint star forming galaxies at $z \sim 2$, even the extreme star formation rates expected for the $z > 4$ starbursts would not correspond to sufficiently high radio flux densities to be detectable by typical radio imaging surveys. This situation was remedied by the MPIA-led VLA-Cosmos survey. The VLA-Cosmos survey provides not only sufficient depth at radio wavelengths, but also a large enough area to detect these extremely rare $z > 4$ starbursts.

A recent breakthrough in the study of early massive star formation occurred when, for the first time, a prominent galaxy overdensity in the early universe was revealed barely $1 \sim$ Gyr after the Big Bang ($z = 5.3$). Since the merger probability and the massive star formation activity induced by this event should be enhanced in early overdense regions, it was the search for high redshift starbursts that paved the way for this discovery. The most massive starburst in this overdensity has been dubbed 'AzTEC-3' and has been studied in detail (see below). Around this starburst are three additional sources that are unambiguously confirmed to be at $z = 5.3$, while six more objects in the surroundings of AzTEC-3 show broad-band colors that are consistent with the same redshift. Overall, this proto-cluster has a physical size of at least 13 Mpc and contains a minimum total matter equivalent of 4×10^{11} $M_{\odot}$.

A prerequisite for such detailed insights was to constrain the total baryonic (i.e. gas and stellar) mass content of AzTEC-3. Deep interferometric observations of carbon monoxide using the Iram Plateau de Bure interferometer as well as the EVLA were key to constrain the total gas mass. This example therefore underlines the importance of interferometric observations in the mm-regime for high-redshift sources. Such interferometric studies of high redshift starbursts at mm-wavelengths also serve as pathfinders for observations that the upcoming Atacama Large Millimeter Array (Alma) will carry out routinely.

Molecular Gas in a $z = 4.05$ Sub-milimeter Galaxy

The Formation of Massive Galaxies

As discussed in the previous section, the massive elliptical galaxies observed out to redshifts of $z > 2$ are thought to be descendants of even earlier massive starburst galaxies. These massive starbursts have been detected in the form of sub-millimeter galaxies (SMGs) – dusty, gas-rich galaxies that are believed to be primarily driven by intense star formation (with rates up to 1000 $M_{\odot}\,yr^{-1}$). A fundamental question is: what drives their intense star formation? The emerging picture is that the majority of SMGs are actually pairs of merging galaxies. The interaction between the member galaxies induces a starburst, resulting in the huge luminosities we observe. An alternate hypothesis has also been put forward, however, in which SMGs are fueled by cold mode accretion (CMA). In this scenario, their star formation is sustained by smooth infall and accretion of smaller, gas-rich satellites. This theory has been successful at explaining some of the key properties of SMGs, including their stellar masses and clustering scales.

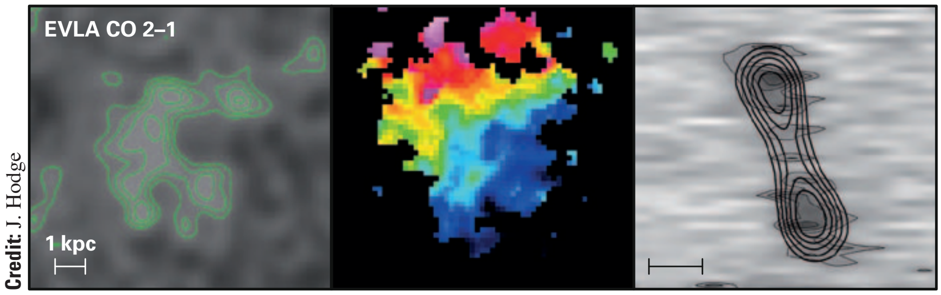


Fig. III.4.3: EVLA CO 2–1 emission from the $z = 4.05$ sub-mm galaxy GN 20 at 0.19″/1.2 kpc resolution. *Left:* Velocity-averaged map over 780 km/s, showing that the gas is distributed in clumps ≤ 1 kpc in scale. *Middle:* The velocity field of the same region, showing ordered rotation. *Right:* Rotation curve for the data (*greyscale + thin contours*) and our model (*thick contours*). The data are well-fit by a simple rotating disk, implying that the gas has not been recently disturbed by a major merger.

GN20: Learning from the Molecular Gas

In order to gain insight into this question, MPIA researchers have conducted a case study on GN 20, an SMG in the Great Observatories Origins Deep Survey North (GOODS-N) field. Originally detected in the submillimeter wavelength range, it was then identified serendipitously in CO using observations by the IRAM Plateau de Bure interferometer. These observations established its redshift as $z = 4.05$, just 1.6 billion years after the Big Bang. Its huge sub-milimeter flux density makes it one of the most luminous starburst galaxies known at $z > 4$. GN 20 therefore provides an excellent opportunity to study SMGs and their role in early galaxy formation.

In collaboration with colleagues at the National Radio Astronomy Observatory in the US, researchers at MPIA were recently awarded over 100 hours on the Expanded Very Large Array (EVLA) in order to study the molecular gas in GN 20 via observations of the CO 2–1 transition. These high spatial, high spectral resolution data allow a detailed analysis of the gas on scales as small as ~1 kpc. They also enable an analysis of the cold gas dynamics, something which was not possible with the restrictions of the old Very Large Array (VLA) correlator. These state-of-the-art data therefore give new insight into the detailed physical processes involved in early massive galaxy formation.

The velocity-averaged CO 2–1 emission from GN20 is shown in Fig. III.4.3 (*left*). This is the highest–fidelity map ever obtained of the molecular gas distribution in a distant galaxy, and it shows that the gas is well-resolved and distributed in a partial ring ~3 kpc in diameter. In addition to the extended, ring-like component, individual clumps of gas are visible which are still unresolved at 1 kpc resolution.

The extension of the gas and its multiple clumps are not what you would expect from a major merger, where the induced star formation is generally tightly concentrated in the galactic nucleus. A quantitative analysis of the clumpiness supports this notion, suggesting that the gas distribution is not the result of a major merger.

An analysis of the gas kinematics is another important piece of the puzzle, and one that is now possible with these high-spectral resolution data. The velocity field of the gas (Fig. III.4.3, middle) shows ordered rotation, which we have modeled with the software. This is something that is rarely done at such high redshift but is made possible by the resolution of depth of this data. Our modeling of the molecular gas shows that its rotation curve can be well-fit by a simple rotating disk (Fig. III.4.3, right). This implies either that the disk has not been strongly disturbed by a major merger, or that, if it has, the merger happened long enough ago that the gas has had time to reestablish itself into a rotating disk. Combined with the analysis of the gas clumps, our results imply that GN 20 may not be a major merger as most SMGs are claimed to be. Rather, the evidence suggests that GN 20 is a clumpy disk fed by cold mode accretion of minor mergers or the proto-intracluster medium.

Dust and Molecular Gas of Giant Lyα – emitting Nebulae

Another class of high-redshift objects actively studied at MPIA are Lyman α nebulae (also known as Lyα "blobs"). These blobs are spatially extended sources at $z = 2-5$ (i.e., 1–3 billion years after Big Bang) with enormous sizes (~ 100 kpc) and copious Lyα emission. The gas clouds are highly-clustered, lying in massive dark matter halos of $\sim 10^{13}\ M_{\odot}$ that will evolve into the clusters of galaxies seen today. Thus, Lyα blobs mark the formation of the most massive galaxies and their early interaction with the intergalactic medium (IGM). However, since their discovery roughly a decade ago, these Lyα blobs have persisted in being one of the most mysterious astronomical objects known. Questions such as what powers these gigantic gas halos, and whether the surrounding gas is outflowing from or infalling into the embedded galaxies, are poorly constrained and intensely debated.

In order to resolve these issues, one first needs to constrain their energy budget. In other words, the total luminosities of the galaxies within or in the vicinity of the Lyα halos should be compared to the available energy with the observed Lyα luminosities. Infrared (IR) and (sub-)millimetre observations provide complementary information by detecting and constraining the luminosity of any dust-enshrouded and obscured power-source (star-forming or AGN) within the nebula. Despite the enormous star formation rates indicated by the far-IR (FIR) luminosities of some Lyα blobs (up to $\sim 1000\,M_\odot\,yr^{-1}$), their molecular gas content, where the stars should form, is largely unconstrained. Is there enough cold molecular gas to power star formation in the Lyα blobs? Or is molecular gas depleted rapidly due to galactic-scale feedback either by the shocks driven by superwinds or the photoionization due to AGNs?

Researchers at MPIA have carried out extensive sub-millimeter and CO line observations of two of the most well-known Lyα blobs using various facilities (including the IRAM 30-m telescope and Plateau de Bure Interferometer) in order to constrain the bolometric luminosities, dust properties and molecular gas content of Lyα blobs. From the (sub-)millimeter continuum observations, it was found that one Lyα blob has a fairly large FIR luminosity of $\sim 4.0 \times 10^{12}\ L_{sun}$, comparable to high-$z$ SMGs and ULIRGS. In the other case, however, no (sub)millimeter source has been detected down to ≈ 0.44 mJy beam^{-1} at $\sim 2''$ resolution, which is amongst the deepest observations ever carried out at ~ 1 mm on a single target (Fig. III.4.4). This non-detection contradicts previous claims that this Lyα blob is harboring ultraluminous IR galaxies that can explain the observed copious Lyα emission if a small fraction of total energy is redirected to Lyα. Despite significant efforts, no CO emission line is detected in either Lyα blob, placing a sensitive upper limit on their molecular gas mass, $M(H_2) < 1-3 \times 10^{10}\,M_\odot$ which is modest compared to those of high-redshift QSOs and sub-mm galaxies (Fig. III.4.4). These results thus shed some light on the dust and molecular gas content of these enigmatic Lyα blobs. Clearly, the unprecedented capabilities (sensitivity and spatial resolution) of ALMA will be critical in further studying dust and molecular gas in these interesting systems.

"The Dusty Young Universe" – A HERSCHEL Guaranteed Time Project

While the presence of dust in galaxies locally and at intermediate redshifts has been known for many years, recent studies of high redshift ($z > 5$) active galaxies have demonstrated that dust emission seems to be common already one billion years after the Big Bang, i.e. when the Universe was less than one-fourteenth of its current age. Despite these advances, only a handful of objects have been studied, and the wavelength coverage of the observations largely excludes the far-infrared (FIR) regime in most cases. In order to overcome these limitations in the study of dust in the high-redshift universe, a MPIA HERSCHEL key project combines the unique observational capabilities of the SPITZER Space Telescope and the HERSCHEL Space Observatory to produce a statistically significant sample of 71 quasars at $z > 5$. The data from

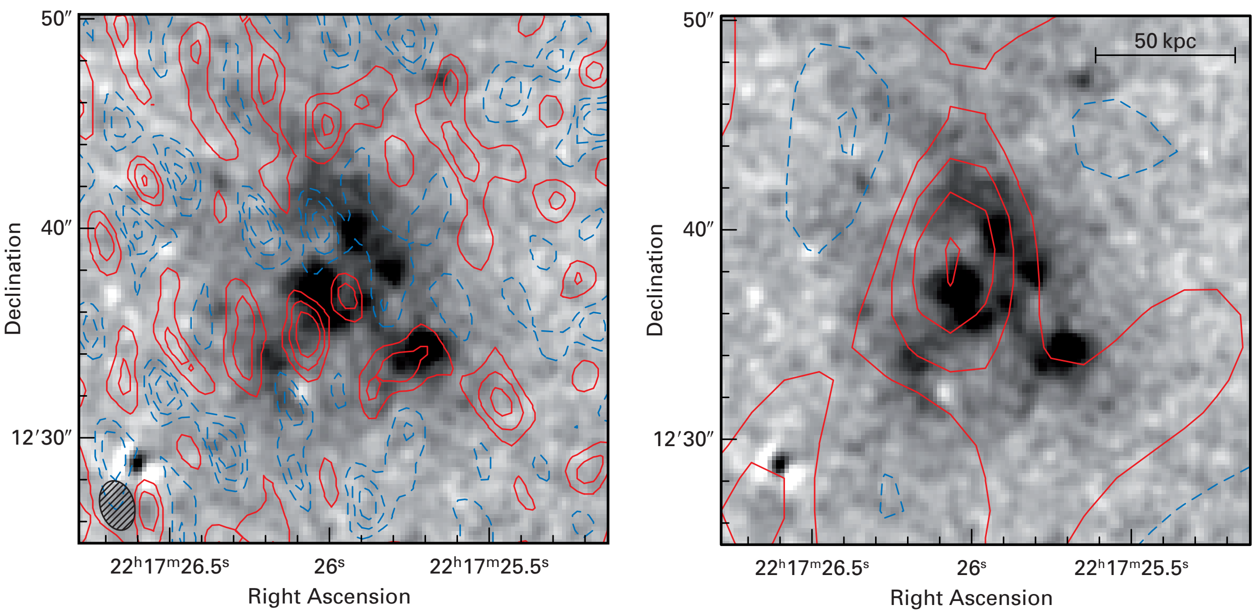


Fig. III.4.4: *Left:* PdBI 1.2 mm continuum contours of a Lyα blob (SSA22-LAB01) superimposed on the SUBARU / SUPRIME Lyα image (courtesy of Y. Matsuda). *Right:* PdBI integrated CO (3–2) channel map. The CO (3–2) line is marginally identified at the center.

Credit: J. Hodge

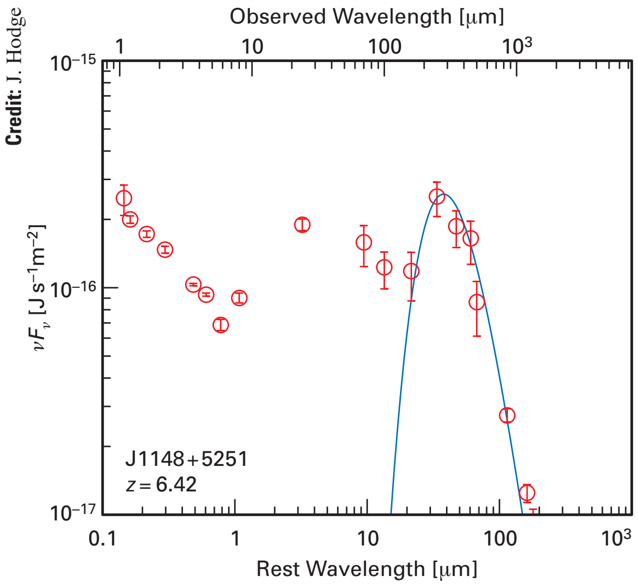


Fig. III.4.5: Full UV through FIR spectral energy distribution (SED) of one of highest redshift quasars known, J 1148 + 5251 at $z = 6.42$. This SED consist of our new HERSCHEL photometry supplemented by SPITZER data and information from the literature. This quasar is observed as it was where the universe was less then a billion years old. Still, we see prominent dust emission from star formation, here indicated by the black body fit ($T \sim 65$ K) in the FIR. At rest frame wavelengths smaller than ~ 1 μm, the power-law slope of the emission indicates that here the accretion disk dominates the observed SED. The near- and mid-infrared flux between $\sim 1 - 20$ μm comes from nuclear dust which is directly heated by the accretion disk.

these observations provide comprehensive photometric coverage of the full infrared signature of dust emission for objects that are located in the earliest cosmic times currently accessible.

The SPITZER data substantially support the presence of hot ($T \sim 1000$ K) dust in essentially all of the observed high-redshift quasars. This dust emission is powered by heating through the continuum emission from the accretion disk surrounding the central supermassive black hole. Careful comparison with similar data on quasars at lower redshift and lower luminosity shows that the hot dust content does not seem to depend on these parameters. This supports the notion that the nuclear dust structures in quasars remain virtually unchanged over most of the age of the universe. More so, it indicates that nuclear structures similar to those in local quasars have already been formed within the first billion years after the Big Bang.

The new HERSCHEL observations allow, for the first time, the systematic exploration of the mid-infrared (MIR) and FIR emission of quasars at high redshift. Combined with the SPITZER data, the new HERSCHEL observations confirm our previous findings for two exemplary objects; namely, that the dust in most quasars at high redshift shows a wide range of temperatures, from cool components ($T \sim 100$ K) up to near sublimation ($T \sim 1500$ K), again very similar to their siblings at much later cosmic times. Remarkably, a small but significant number of the $z > 5$ quasars stand out by showing very powerful dust emission at $T \sim 60$ K (Fig. III.4.5). The luminosity of this component alone exceeds the total energy output of typical galaxies (like our Milky Way) and signifies vigorous star formation. Here, stars are born from the interstellar medium, building the early quasar host galaxies at rates $> 1000\ M_\odot\,yr^{-1}$.

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National Radio Astronomy Observatory (NRAO), USA

IV. Instrumental Developments and Projects

Within this chapter, we report on current activities regarding our instrumentation projects and related technical developments. Since the rather large number of ongoing projects, a small selection is presented here which is representative, anyhow. Since this selection varies over the years, we encourage the reader to have also a look into other Annual Reports of the institute.

IV.1 First Results from LUCI 1, news about LUCI 2

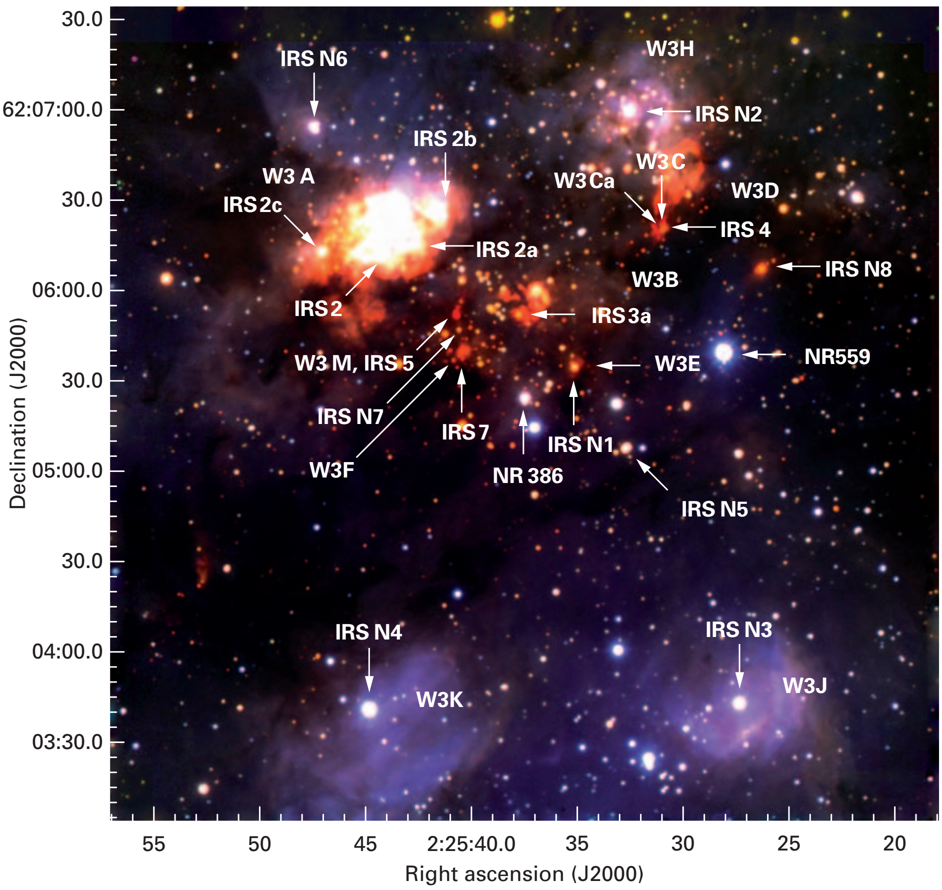
Following the last commissioning time at the end of 2009, the Science Demonstration Time (SDT) has been successfully concluded. Subsequently, since December 17, 2009 LUCI 1 is available for scientific projects, thus, 2010 reflects one full year of scientific observations with LUCI1 (formerly called LUCIFER 1/2). LUCI 2 is currently being assembled and tested at MPIA.

One year of LUCI 1 scientific application

Six LBT-B observing blocks have been performed during 2010. Direct imaging and MOS spectroscopic modes have been used excessively. As an example for a direct imaging application, a three color image of W3 Main, a star formation region in the northern constellation Cassipeia, is shown in Fig. IV.1.1. Within the same region MOS-spectroscopy has been performed.

The AO-application of LUCI 1 is not yet available: First, because the left side telescope unit is not yet equipped with an adaptive secondary, secondly, because the N30-camera planned for AO-imaging and spectroscopy had to be redesigned due to technical problems. This option will be available in LUCI 2 for Preliminary Acceptance in Europe.

Fig. IV.1.1: 4.5 × 4.5 arcmin² field of W3 Main as a three color image: J blue, H yellow, K red.



Credit: A. Bik

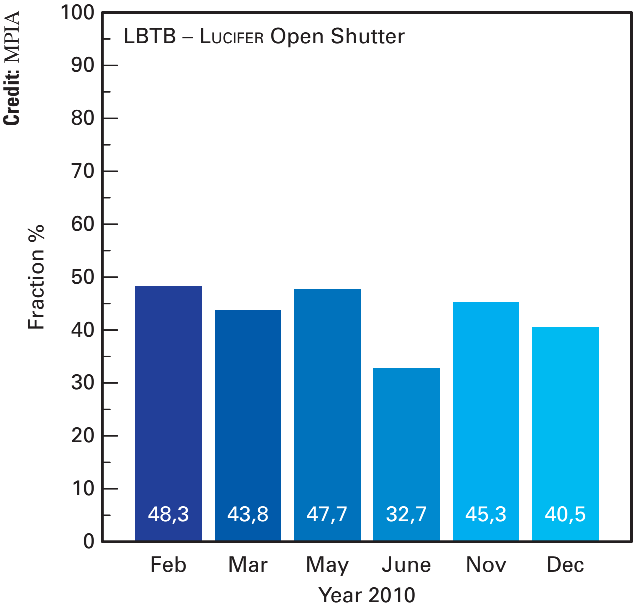


Fig. IV.1.2: Open Shutter statistics for LBTB observing blocks in 2010.

An overview over the efficiency of the LBTB observing blocks in 2010 (open shutter statistic) is shown in Fig. IV.1.2. A medium value of 43 % open shutter fraction has been achieved.

Status of LUCI 2

End of March 2011, LUCI 2 will finally be moved from MPE in Garching to the MPIA Experimental Hall for full assembly. Then, the MOS-unit will be integrated and first functioning tests will be performed.

Several technical improvements will be tested in LUCI 2 and then implemented in LUCI 1 – in particular some modifications improving the reliability of the MOS unit. After Preliminary Acceptance in Europe, LUCI 2 will be available for Commissioning in 2012.

Further improvements of the read-out software for LUCI 1 and LUCI 2 have been implemented, especially concerning sub-windowing, idle modes and suppression of overflow / persistence effects.

Rainer Lenzen, Roland Gredel,
Werner Laun, Michael Lehmitz,
Ulrich Mall, Vianak Naranjo,
Clemens Storz, Karl Wagner,
in collaboration with:
Landessternwarte Heidelberg

IV.2 The CARMENES Project

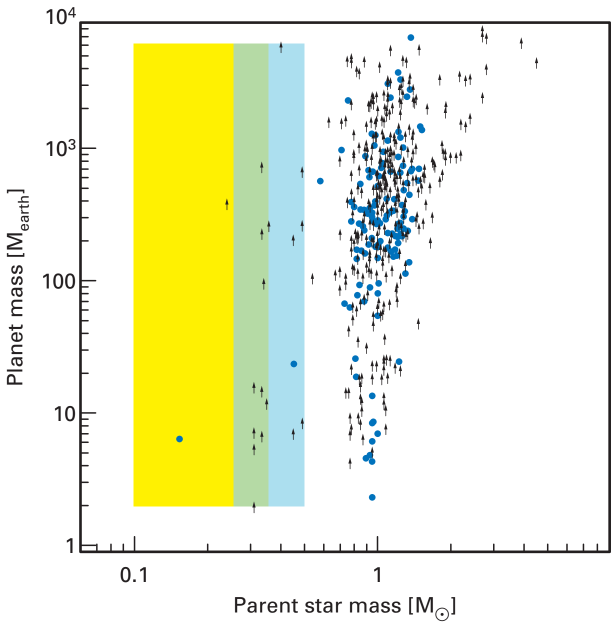
CARMENES (Calar Alto high-Resolution search for M dwarfs with Exo-earths with Near-infrared and optical Èchelle Spectrographs) is a next-generation instrument to be built for the 3.5 m telescope at the Calar Alto Observatory (Spain) by a consortium of eleven Spanish and German institutions, which are Instituto de Astrofsica de Andaluca (Granada), Institut de Ciéncies de l'Espai (Barcelona), Universidad Complutense de Madrid, Instituto de Astrofisica de Canarias (Tenerife), Departamento de Astrofisica (Universidad Complutense de Madrid), Centro Astronomico Hispano-Aleman (Calar Alto), Landessternwarte Königstuhl (Heidelberg), Max-Planck-Institut für Astronomie (Heidelberg), Institut für Astrophysik (Göttingen), Thüringer Landessternwarte (Tautenburg), Hamburger Sternwarte.

The CARMENES instrument consists of two separate Èchelle spectrographs namely an optical spectrograph covering the wavelength range 0.55 – 1.0 µm and an NIR spectrograph with a wavelength range of 0.95 – 1.7 µm (spectral resolution 85 000). Both spectrographs are fed by fibers from the Cassegrain focus of the telescope. The spectrographs are housed in vacuum tanks providing the temperature-stabilized environments necessary to enable a 1 m/s radial velocity (RV) precision employing a simultaneous calibration with an emission-line lamp.

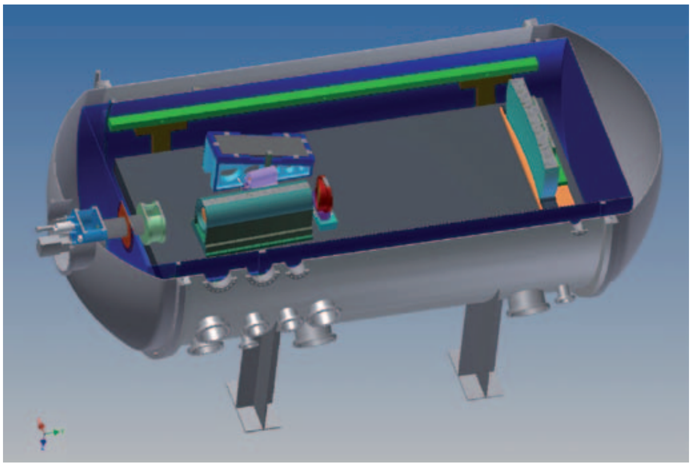
The main scientific aim of CARMENES is conducting a five-year exoplanet survey targeting about 300 M stars mostly later than M3 – M4 (i.e., $M < 0.3\,M_\odot$). The project has been optimized for a search for terrestrial planets in the habitable zones of low-mass stars, which may well provide our first chance to study environments capable of supporting the development of life outside the Solar System. With its unique combination of optical and near-infrared spectrographs, CARMENES will provide better sensitivity for the detection of low-mass planets than any comparable instrument, and will be a powerful tool for discriminating between genuine planet detections and false positives caused by stellar activity, which have plagued planet searches employing spectrographs with a smaller wavelength coverage. With its clear scientific focus and the large number of nights (600 – 750) available at the Calar Alto 3.5 m telescope during the 2014 – 2018 time frame, the CARMENES survey will be a very competitive project, and leave a lasting legacy of 50 to 100 planets in the habitable zones of low-mass stars. A long-term radial velocity precision of 1 m/s per measurement (1 sigma) will permit to attain this goal. For stars later than M4 ($M < 0.25\,M_\odot$), such precision will yield detections of super-Earths of 5 M_{earth} and smaller inside the entire width of the habitable zone (HZ). In addition, the HZ of all M-type dwarfs can be probed for super-Earths. Thus, a RV precision of 1m/s can trigger a breakthrough in exoplanet research in the spectral range of mid and late M-type stars. Fig. IV.2.1 illustrates that the mass regime CARMENES is exploring is so far rather poorly investigated, because no suitable instruments were available so far.

In addition to the science preparation/exploration and management support the MPIA is mostly involved in providing the detector and cryostat (together with the readout electronics and software) for the NIR Èchelle spectrograph of CARMENES. The layout of the NIR spectrograph (see also Fig. II.2.2) is a cross-dispersed Èchelle. The light from the fiber exit is converted to the collimator focal ratio and afterwards sliced by a two-slice image slicer. Dispersion is provided by a 2R4 mosaic grating, and a grism cross-disperser separates the orders. The beam diameter is 136 mm; the resolution is 85 000. The cooling concept of the CARMENES NIR spectrograph is a continuous-flow cooling system. It employs a radiation shield internal to the vacuum tank. The cooling agent is temperature-stabilized N2 gas provided by an external unit. A low operating temperature (~ 80 °C) can be achieved relatively easily. The selected infrared

Fig. IV.2.1: Planet mass as a function of planet host star mass. As evident from this diagram little is known on the frequency of planets below 0.7 $M_\odot$ and in particular below 0.25 $M_\odot$ and therefore Carmenes will in particular search for terrestrial planets orbiting stars with masses below 0.25 $M_\odot$ (*yellow-shaded region*). Upwards pointing arrows, indicating lower limits on the planetary mass, are based on radial velocity observations, while filled dots are based on transiting planets.



Credit: I. R. Canudas



Credit: MPIA

Fig. IV.2.2: Horizontal cut through the vacuum tank of the NIR spectrograph showing the optical bench with the main optical components. The detector cryostat to be built by the MPIA is visible in the very left hand part of this drawing.

array is a mosaic of two HAWAII-2RG detectors with a cutoff wavelength of 1.7 µm which allow a relatively high operating temperature (~100 K). The peak efficiency of the NIR spectrograph will be 11 % at 1000 nm (including atmosphere, telescope, fiber feed, and detector).

Reinhardt Mundt

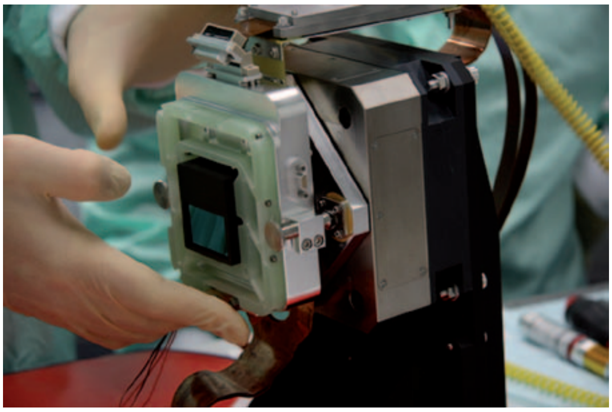
IV.3 Sphere – the planet finder

Sphere – Spectroscopic and Polarimetric High-Contrast Exoplanet Research – is the name of a 2nd generation VLT instrument for direct imaging of extrasolar planets at the Paranal Observatory. It will be composed of an extreme adaptive optics system – using a deformable mirror (DM) with 1600 actuators and running at a loop frequency of 1.5kHz, dedicated coronagraphs, and three focal plane instruments: The differential polarimeter ZIMPOL operating at visual wavelengths, an integral field spectrograph working in the Y- and J-band, and a versatile Near-Infrared (NIR) differential imager essentially similar to CONICA.

Sphere is being built by a consortium of 13 European institutes with the "Laboratoire d' Astrophysique et Observatoire de Grenoble" (Laog) being the P.I. institute and MPIA the Co-P.I. Institute. The project had its phase-B kick-off meeting in March 2006, and successfully passed all the intermediate milestones and reviews up to the final design review. All components have been purchased and the sub-systems are currently being assembled at various locations throughout the consortium. Overall integration in Grenoble is foreseen in 2011.

Sphere was planned in 2006 to cost about 174 FTE and 6 M€ in hardware, including some FP6-funded components. MPIA's contribution is planned to be 18 FTE and 500,000 €, resulting in a 10% share in the project. Miraculously, these numbers still hold, with the notable exception of a miss-designed DM, which needs to be re-designed and manufactured. While still under guarantee, the consortium and Eso will have to make a contribution of about 250 k€ in order to procure a new Deformable Mirror next year. On the consortium side, this will take all our contingencies.

Fig. IV.3.1: The detector motion stage with the engineering grade detector, being mounted for the first time into the Irdis system.



Credit: M. Feldt

MPIA's prime responsibility in the project is the data reduction and handling software, essentially everything between the target list (including the target list itself) and the final list of candidate detections – of course including data reduction and analysis. Additionally, MPIA is providing some hardware components, like a detector motion stage for the NIR imager, and the two atmospheric dispersion corrector units. These units have been completed and are currently undergoing tests at MPIA. So far, all specifications are being met.

The data reduction pipeline is one of the most complex ones produced for Eso instrumentation so far. The total number of "recipes" foreseen is an unprecedented 66. A "recipe" is a complete data reduction tool for a complete set of scientific or calibration data taken in a given mode of the instrument. For Sphere, recipes exist e.g for conventional tasks like producing a master dark frame from a series of dark calibration images, but also, e.g., for setting up the reconstruction of monochromatic images from IFS data using a set of dedicated calibration frames. For the first time, the Sphere pipeline will also perform a limited astrophysical analysis of the data fully automatically: it will look for faint point sources next to the bright central stars in the field, thus identifying potential planetary candidates.

The approach taken to produce the pipeline is that of so-called agile software development. Here, rapid prototypes of all the recipes are produced and undergo immediate testing on simulated and laboratory data. The results of the tests are immediately taken into account during the first round of re-factoring to eliminate bugs early-on. Additionally, frequent meetings with the responsible (sub-)system scientists are held to analyze the results and re-define the specifications, particularly on optional and standard behavior of individual recipes, and the input and output formats. There are also weekly interactions with Eso and the prototype recipes are regularly tested also on Eso infrastructure. In fact, Eso has in the meantime changed their specification document, adopting our method of software development as future standard for all new instruments. By the end of 2010, the pipeline was for the first time "complete" in terms of prototypes, i.e. all recipes with the exception of monitoring and very high-level analysis recipes existed and where able to reduce data. New releases of the complete system will now follow at monthly intervals.

The scientific reward for the effort of building the instrument will manifest itself in 260 nights of guaranteed observing time (GTO), about 205 of which will be dedicated to a large Nir survey for exoplanets. It was decided early-on in the consortium not to divide the GTO between participating institutes, but to conduct a large common survey to ensure a homogenous data set and

Credit: (beide Bilder) M. Feldt

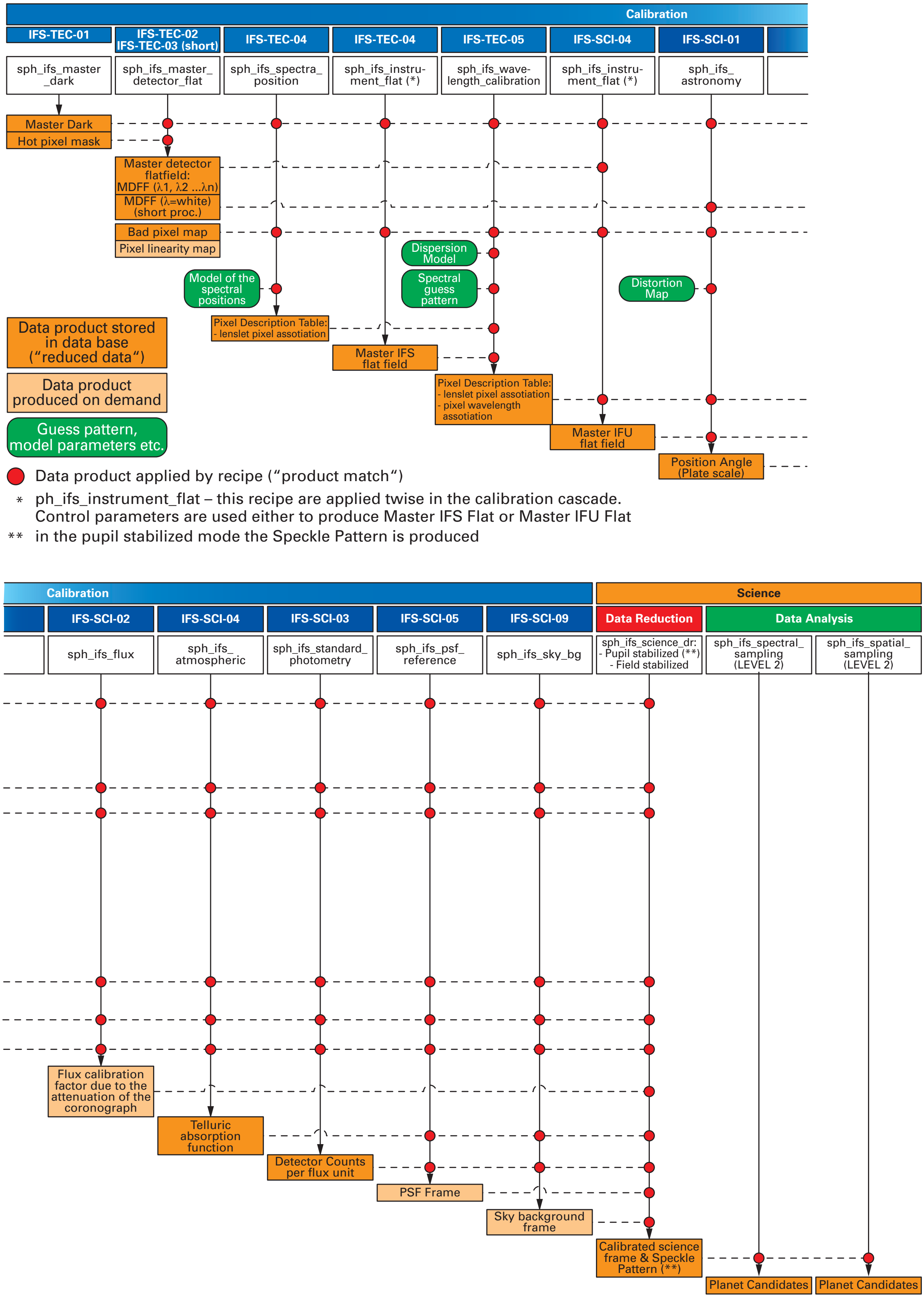


Fig. IV.3.2: Development cycles of the data reduction pipeline between FDR and the end of 2010.

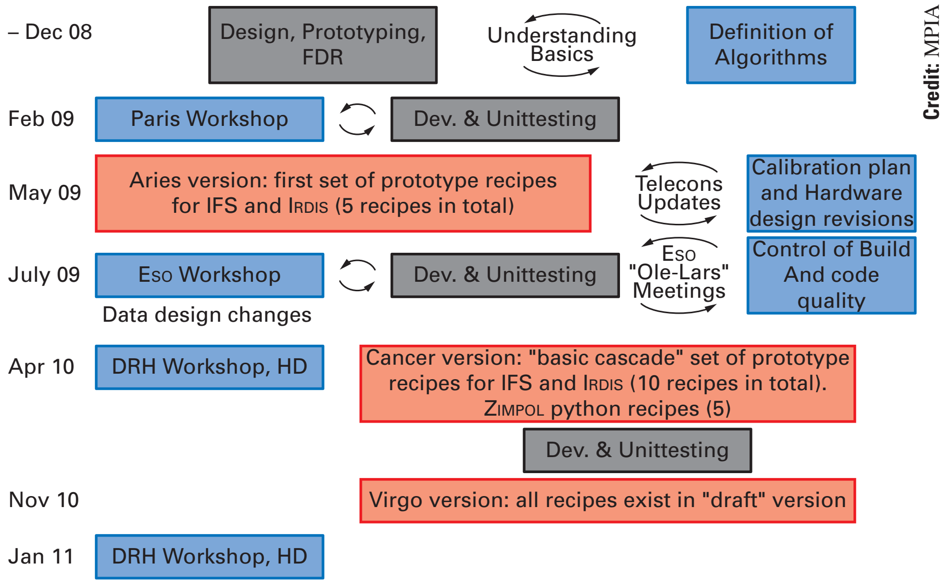
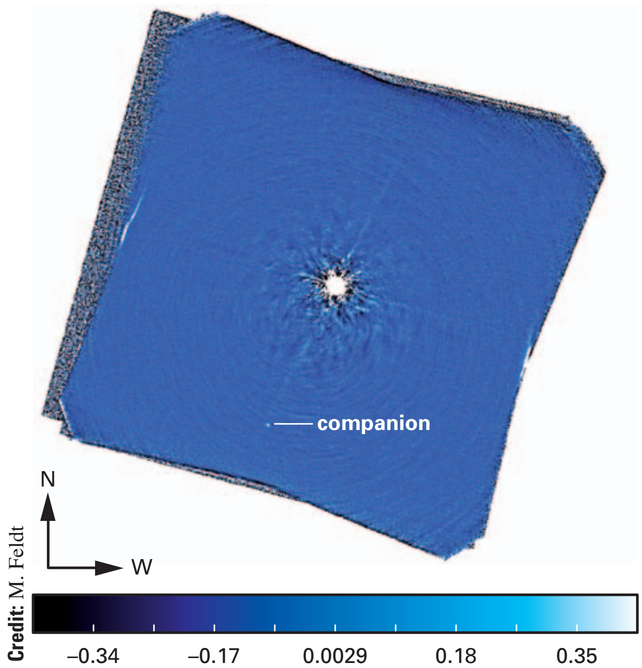


Fig. IV.3.3: The data reduction cascade of IFS.



analysis. Preparations for this program are now well under way. A target data base has been set up, containing about 600 targets categorized in 3 mass and 2 age bins: Younger than 150 Myr and older than that, and low-mass ($< 0.8\,M_\odot$), solar mass, and massive ($> 1.3\,M_\odot$) stars. While the low-mass bins are still being populated, the process of defining the rules by which targets will be selected for actual observation (less than half of the 600 in the data base) has been initiated by the science group. A large preparatory program using the existing NACO instrument at the VLT has also been started and is currently delivering its first data sets.

If everything continues to go well, the first commissioning run is foreseen for late 2012, and the GTO program will commence in 2013.

Markus Feldt

Fig. IV.3.4: Second epoch confirmation image of a companion roughly 4″ from its central star detected during the NACO preparation program for the SPHERE survey. The image demonstrates typical artifacts of the "angular differential imaging" technique, a key method also in the SPHERE data reduction pipelines.

IV.4 Special developments in the technical departments

High-resolution tip-tilt optical mount

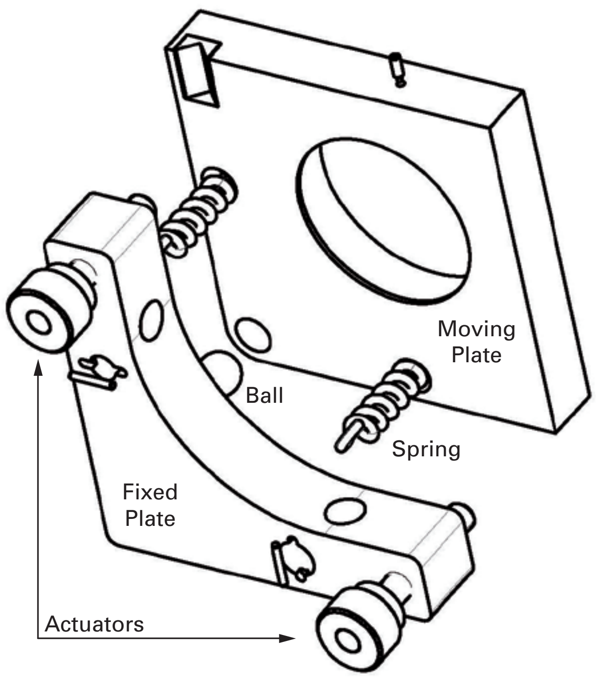
Tip-tilt optical mounts (manual or motorized) for adjusting optical beams are widely in use in optical experiments. Many companies offer parts from stock for different optical diameters. Fig. IV.4.1 shows the design principle of a manually driven optical mount.

The manual or motorized actuators are connected by springs with the moving plate. Drawbacks of this design are that it limits the resonant frequency of the whole system and that the motorized actuators are often too big for the available space.

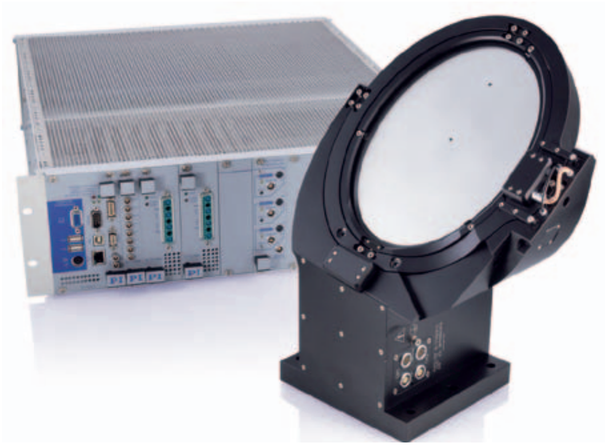
Recent developments

The interferometric beam combiner LINC-NIRVANA (LN) for the Large Binocular Telescope (LBT) has several motorized optical tip-tilt mounts. The dichroic mirrors separating the warm and cold channels are particularly challenging. These optical components split the light between the wave front sensor (visible) and the beam combiner (infrared). Mounts with standard actuators cannot achieve the needed performance for stability, eigenfrequency, resolution and space constraints.

Fig. IV.4.1: Design principle of a tip-tilt mirror mount.



Credit: MPIA



Credit: MPIA

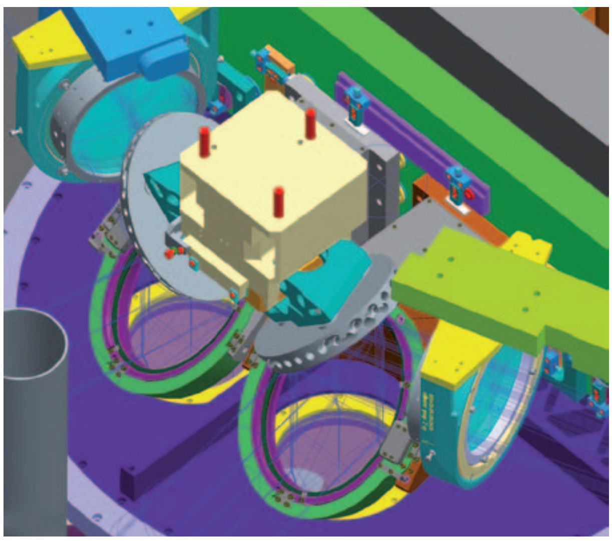
Fig. IV.4.2: Tip-Tilt warm dichroic mount for LINC-NIRVANA.

The important requirements are:

Resolution	< 0.5 arcsec
Eigenfrequency	> 110 Hz
Stability	< 20 arcsec (must be fulfilled up to a telescope distance of 60° from zenith)

After several internal and external discussions about the drawbacks of common tip-tilt mounts, MPIA initiated the design of a novel unit using NEXLINE® actuators from Physik Instrumente in combination with stiff flexible pivots at the rotation axes. The NEXLINE® actua-

Fig. IV.4.3: Integration of the two dichroic mounts into the LINC-NIRVANA instrument. Note that the base structures (*shown in grey*) of the mounts extend to the upper right in this image.



Credit: MPIA

tors combine long travel ranges with high stiffness and high resolution (better than 0.1 nm). The drive can always be brought to a condition with zero-voltage on the individual piezo elements and with the full holding force available to provide nanometer stability, no matter where it is along its travel range.

The piezo motors of the drive consist of several individual piezo actuators and generate motion through a succession of coordinated clamp/unclamp and expand/contract cycles (please see the website www.physikinstrumente.de for more information about the working principle).

Fig.IV.4.2 shows the compact design of the tip-tilt mount, as well as the drive electronics built by Physik Instrumente. The actuators including sensors are fully integrated into the housing. Two moving frames are suspended by flexible pivots and the piezo motors are directly coupled without any springs. MPIA was involved in the complete design process.

Cooperative tests showed the excellent performance:

Resolution	=	0.3 arcsec (closed loop), 0.1 arcsec (open loop)
Eigenfrequency	=	125 Hz
Stability	<	15 arcsec

The mount has a very high eigenfrequency of 125 Hz. Standard mounts using flexible pivots typically achieve a maximum eigenfrequency of only 30 Hz.

Fig. IV.4.3 shows the integration of the two tip-tilt mounts into the very crowded LINC-NIRVANA environment.

Ralf-Rainer Rohloff

Fig. IV.4.4: Flight model of the filter wheel for MIRI.

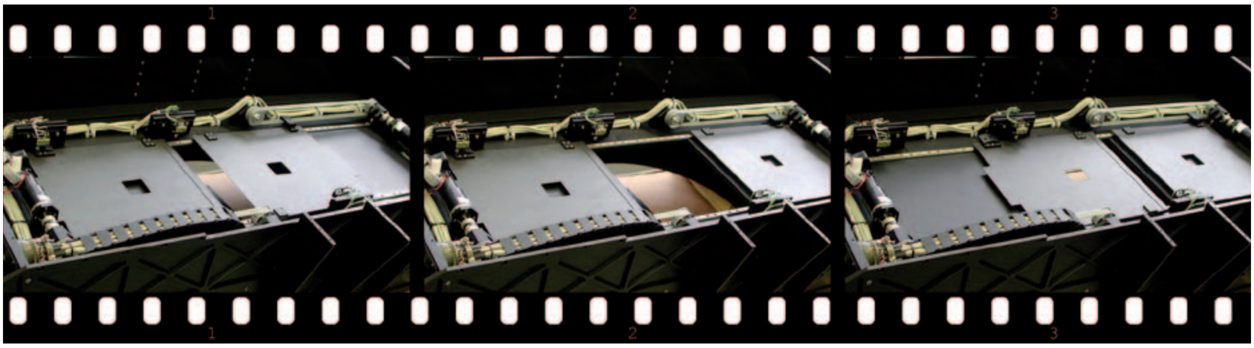
Credit: MPIA

A versatile motion control system for astronomical instrumentation

Modern instruments for astronomical telescopes require the use of diverse actuators and electro-mechanical devices. They serve different purposes like high precision alignment of opto-mechanical units, selection of optical elements in the light path, detector dithering, vibration compensation, and many others. Each motion function that is to be realized defines specific requirements on the actuator. In complex instruments these requirements are very different, and it is usually not possible to fulfill them all with a single actuator type. Consequently, a wide variety of actuators and motion types are used. The control electronics system of an astronomical instrument must therefore be able to operate all of these actuators and motion types.

A specific challenge is accommodating mechanisms that operate in infrared instrumentation at cryogenic temperatures down to 60 Kelvin. In this area piezo motors offer promising solutions. To fulfill the wide range of demands a competitive motion control system has been developed by the MPIA Electronics Department. A modular chassis with standardized boards provides best solutions for extensive tasks. High and low power DC servo motors, brushless DC servo motors, stepper motors and piezo motors with different technologies are supported. Diverse position feedback capabilities, like incremental and absolute encoders for non cryogenic and capacitive sensors and resolvers for cryogenic applications, are provided.

This system has already been used successfully in already operating instruments such as LUCI (LBT) and LAIWO (Wise Observatory) and it is also being implemented in other instruments which are still under development like LINC-NIRVANA (LBT), SPHERE (ESO VLT), and PANIC (Calar Alto).



Credit: MPIA

Fig. IV.4.5: Focal plane shutter in LAIWO.

Cryo torque-motor drive in MIRI and NIRSPEC

MIRI and NIRSPEC are two of the four scientific instruments at the James Webb Space Telescope (JWST). The MPIA is involved in the development of motorized wheel mechanisms like filter and dichroic wheels. A total of six wheels of different sizes and forms are integrated in these instruments. Common to all wheels is a cryo torque-motor, specially developed for these applications, and the ratchet mechanism, which holds the wheel at a specific position (see Fig. IV.4.4).

An open loop control method for the motor is used. In order to keep the average heat dissipation of the mechanism low, the motor is powered with a characteristic pulse of a few milliseconds when moving from one position to another, and then it is powered off during observation. The characteristic drive signal is a current wave form and it is calculated such that the motor is first pulled out of its start position and then decelerated to smoothly reach the next position. This special operation method requires that the motor electronics output the pre-calculated drive signal with a precision better than 1 % over the entire current range of a few milli-Amperes to 1 Ampere. Another special requirement is the necessity to operate the motor at cryogenic temperatures as well as at room temperature. Since the motor is optimized for cryogenic temperatures, its resistive load grows by a factor of a hundred at room temperature. This requires that the motor driver is able to adjust its output voltage from a few Volts up to almost 100 Volts.

Focal-plane shutter in LAIWO

The Large Area Imager for the Wise Observatory (LAIWO) is a scientific instrument at the 40 inch telescope of the Wise observatory in Israel. It has 5 CCD detectors which are operated at minus 100 °C and which are cooled by liquid nitrogen. Four CCDs for the scientific image are ordered around a central Guider-CCD. A motorized focal-plane shutter permits an exact control of the exposure time. Wide field imagers require a particularly even illumination of the CCD array for flat field exposures. Movement over the area to be covered must be carried out reproducibly, evenly and exactly. Both short and long exposures must be supported.

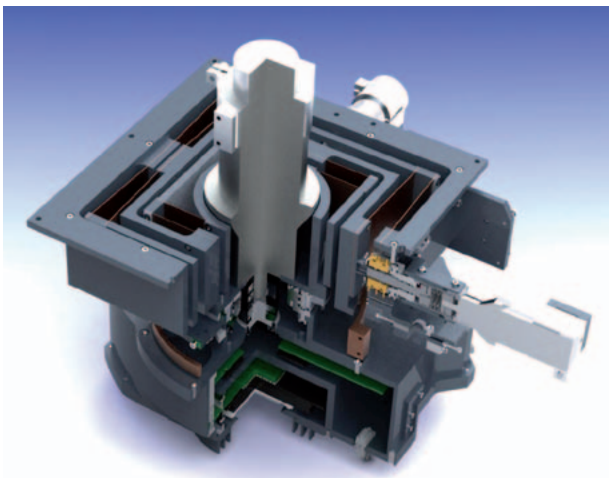
The complete focal-plane shutter is built up on a base plate (see Fig. IV.4.5). Two carbon fiber reinforced epoxy resin plates move on linear ball bearings over the area to be covered. Each plate has a cut-out in the area of the Guider-CCD which makes an exposure of the Guider-CCD possible at closed Shutter. The outside movement of the plates is mechanically constrained. Driven together, the plates overlap with some slope in a reinforced area. The plates are driven by two DC motors over toothed drive belts. Driven to the outside, both plates expose the complete central area over the detectors freely, with no shading.

Detector rotation in LINC-NIRVANA

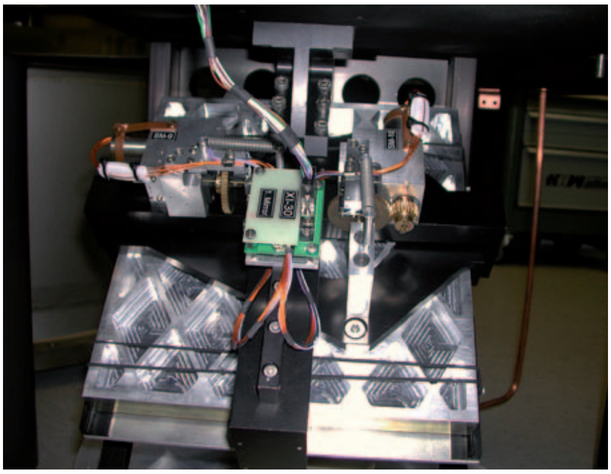
LINC-NIRVANA is an instrument currently under development for the Large Binocular Telescope in Arizona. It will combine the two beams from the two primary mirrors.

A mechanism for realizing detector rotation is implemented. The detector unit (see Fig. IV.4.6) rotates the detector to follow the sky, in order to avoid smearing of

Fig. IV.4.6: Detector unit in LINC-NIRVANA.



Credit: MPIA



Credit: MPIA

Fig. IV.4.7: Cryogenic stepper motors for alignment and active flexure compensation.

the images for longer integration times, when the objects rotate in the focal plane in a pupil-fixed setup for an alt-azimuth telescope. The resolution of the detector rotation mechanism is set to 15 arcsec. For the centering of the detector unit there are two x/y actuators with a resolution of 2 µm. The velocity required for the detector rotation depends on the pointing position of the telescope on the sky. To realize the detector rotation the external profile mode of the motion controller is used. The moving profile is calculated by the host computer and uploaded to the motion controller. After synchronization and start the motion profile can be changed on the fly to adjust the detector movement. Because motor and detector are close to each other and the motor is driven during observation it is important to reduce any electromagnetic emissions by the motor, which can impair the detector performance. Therefore, a low noise linear drive with reduced bandwidth is chosen instead of the usual chopped drive.

Active flexure compensation in LUCI

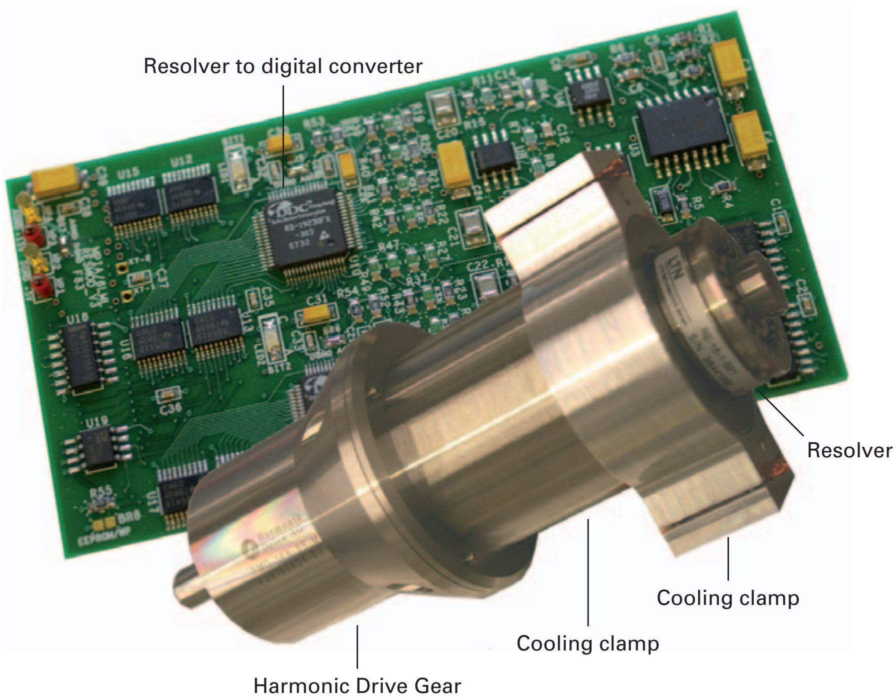
LUCI is a pair of fully cryogenic near-infrared spectrographs and imagers for the LBT, each equipped with three exchangeable cameras for imaging and spectroscopy. The first LUCI instrument has already passed the commissioning phase and entered regular science operations in December 2009.

The first and the last mirrors of the collimator of the instrument are motorized to align x/y tilting during integration. The last fold mirror in front of the pupil is also used during instrument operations to allow an active compensation of image movement on the detector in response to mechanical flexure of the structure.

Stepper motors with resolvers in cryogenic environment

PANIC is currently under development for the Calar Alto observatory in Spain. The camera uses four HAWAII-2RG detectors, each with 2048 × 2048 pixels, from Teledyne Scientific & Imaging, LCC. They are mounted in a mosaic detector array. The complete instrument, including four filter wheels and a cold stop wheel, is built into a nitrogen bath cryostat.

Fig. IV.4.8: The resolver to encoder converter module and the cryogenic actuator.



Credit: MPIA

It is essential to analyze and monitor the rotation axes of the motors driving the wheels of the instrument. Consequently all stepper motors are equipped with resolvers from the company LTN Servotechnik. Several tests have shown, that with a simple rotor modification, the resolvers are working well at 77 K.

Karl Wagner, Matthias Alter, Ralf Klein, Michael Lehmitz, Lars Mohr, José Ricardo Ramos

CCD Rocon system

The new read-out electronics (Roe) for infrared detectors presented in the 2009 annual report will be complemented by CCD specific features in order to be used for the read-out of CCD detectors. This has become necessary, since on the one hand none of the ongoing instrumentation projects justifies the development of a pure CCD read-out electronics, but on the other hand there are a number of CCD applications on Calar Alto and in Heidelberg that are currently operated with outdated ROEs which can no longer be repaired in case of failure.

The final CCD read-out control (Rocon) system will be available as a reproduction template to Calar Alto and other interested parties that have been using CCD systems developed at the institute and now rely on a successor system compatible with their dewars.

The main extensions of the infrared read-out electronics consist of a board to generate phases with adjustable amplitude to drive the CCD, the concept of which was taken over from the previous CCD Roe, an amplifier board with 16 bit digitalization of four channels of CCD data, and I/O for the control of the shutter and the protection relays of the CCD dewars.

The effort for the changeover to the new system is small. The existing CCD dewars will be operated without any change and also the existing user interface will not have to be modified.

Compared to its predecessors the new system will offer a number of improvements such as increased flexibility for the layout of the timing, a larger number of control phases for the CCDs, direct data transfer to the control computer via fibers, and system control via LAN.

In 2010, the hardware was produced, and the system firmware was written. Software for lab tests was adapted, various CCD detectors were read-out in simulation mode, and data files were created.

Karl-Heinz Marien, Florian Briegel, Ralf Klein, Ulrich Mall, José Ricardo Ramos, Clemens Storz

V People and Events

V.1 Looking back at 2010

Not a year goes by at MPIA that is not marked by a wide variety of events and occasions. The year under review is no exception, and the sheer number renders it difficult to make a selection for the purpose of a summary report. From the Scientific Advisory Board to the Haus der Astronomie, from the first HERSCHEL observations to the Institute's prize-winners, there is a great deal to tell about the year 2010.

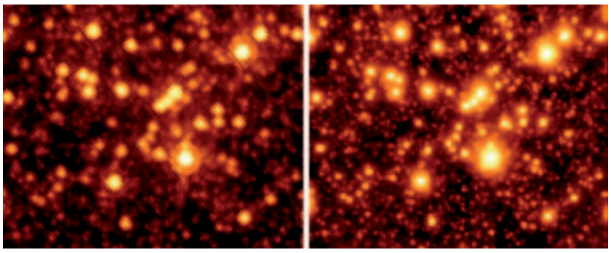
Public outreach activities

Exceptionally, we will start with public outreach activities, and with a reference to the next chapter of this annual report, as section V.2 contains a special report on the progress of activities related to the Haus der Astronomie (lit. House of Astronomy). After the ground breaking ceremony 13 October 2009, construction of this extraordinary building was cranked up to full speed, and on 17 December 2010 – just 15 months later – it was time to hold the topping-out ceremony. At the same time, of course, we kept up our normal public outreach activities, and some new aspects were introduced in the context of continuing to complete the Haus der Astronomie team.

In addition to the activities mentioned in chapter V.2, the Haus der Astronomie team also took part in the following MPIA events: Girls Day (22 April), the extremely successful lecture series Astronomie am Sonntag Vormittag (Astronomy on Sunday Mornings, 13 June to 31 July, see Fig. V.1.1) and supervising schoolchildren during a practical training module of the International Science School Heidelberg (ISH, 18 July to 14 August). The ISH is a project of the city of Heidelberg to promote the exchange of scientifically gifted schoolchildren with Heidelberg's partner cities. The MPIA is a co-participant in the project and member of its Scientific Council, along with the city and other institutes. In addition, the author of this report and the head of the Haus der Astronomie together organized a first major meeting on the topic Public Outreach in Astronomy www.mpia.de/homes/jaeger/index.htm) at the conference of the Astronomische Gesellschaft in Bonn (13 to 18 September); this conference was also attended by numerous MPIA colleagues interested in the scientific presentations. Two successful events from the previous year, the International Year of Astronomy, also extended into 2010: The public lecture series "Galileo's First Look Through a Telescope and Its Consequences Today" (until February 2010) and the exhibition "Himmlisches in Büchern" (lit. The Heavenly

Fig. V.1.1: Again, the MPIA lecture hall was full of visitors during all talks of the public Sunday morning lectures.

Credit: K. Jäger



Credit: LBTO

Fig. V.1.2: One of the first test images (*right*) taken with the adaptive optics at the Large Binocular Telescope as compared to an image of the same region by the Hubble Space Telescope. The better resolution of the LBT image is clearly visible. Both images of a region in the globular cluster M 92 are taken at 1.6 μm (near-infrared) wavelenght.

Lies in Books), hosted by the university library and Heidelberg Centre for Astronomy (until 29 August). Again, the MPIA was a willing participant.

Once again in 2010, there were a large number of guided tours through the Institute. At a total of more than 30 events, which, as ever, would not have been possible but for the generous support of students and staff, visitors were informed about the activities of MPIA. School and college groups accounted for over 50% of these tours, and there were also some VIP visits (see next section).

Special guests and developments at the Institute

Throughout the Institute, the start of the year was marked by intense preparation for the Scientific Advisory Board (Fachbeirat), which was to convene for the first time in two-and-a-half years. The Evaluation Committee visited the MPIA from 23 to 25 March and all staff were delighted that once again, the Institute's scientific performance was assessed as outstanding.

The Board of Trustees also visited us once more. As a governing body, the Board provides important support to the Institute in questions of academic policy, public perception and contacts in society. During its visit on 14 October, the Board elected Prof. Karlheinz Meier of Heidelberg University's Kirchhoff Institute for Physics as its new Chair. Prof. Meier took over from Dr. Hermann-Friedrich Wagner, Assistant Secretary General (retired) from Bonn, who had held the post since 2003; MPIA management is very grateful for Dr. Wagner's untiring support during his tenure.

The Institute management provides detailed information on special developments in the Institute at meetings of both the Scientific Advisory Board and the Board of Trustees, with a particular emphasis on instrumentation projects and science. In this context, the following events from 2010 are worthy of note:

- In December, the Max Planck Society and the Spanish research council CSIC agreed on a contractual extension and financial plan for the continued joint operation of the Calar Alto Observatory until 2018. In addition, the commitment of MPIA technical units enabled the successful completion of an important repair to the 3.5-metre telescope.
- The location for the 42-meter European Extremely Large Telescope (E-ELT) was settled by an ESO committee headed by the MPIA. The Cerro Armazones mountain in Chile's Atacama Desert was selected after intense surveys of a number of suitable places around the world.
- Shortly after the commissioning of LUCI 1 with the Large Binocular Telescope (LBT) in December 2009, the first good scientific spectra and images were published in early 2010 (see also chapter IV.1). LUCI 1 and LUCI 2 are innovative near-infrared cameras with spectrometer, developed by the German LBT partners under the leadership of the Landessternwarte Heidelberg, with significant contributions from the Max Planck Institute for Extraterrestrial Physics in Garching and MPIA.
- The first successful test exposures with one of the LBT's adaptive secondary mirrors were also taken in

Fig. V.1.3: Activities at MPIA's 70 cm telescope at the Girls' Day 2010.

Credit: M. Pössel

2010, delivering much sharper images in the near-infrared *K* band than the Hubble Space Telescope. (see Fig. V.1.2)

- With significant instrumentation input from MPIA, the Herschel space telescope achieved outstanding scientific results in its first year of regular operation (cf. chapter III.1).
- Work was completed on the Miri and NirSpec instruments for the James Webb Space Telescope (JWST), and the cryomechanisms were integrated in the instrument flight models after successful completion of the acceptance tests.
- The Pan-Starrs-1 (PS1) survey has supplied regular data since 2010.
- At the end of 2010, the new collaborative research center "Milky Way" was approved for Heidelberg University with MPIA as a very active participant. This project further strengthens our longstanding, very close collaboration with Heidelberg University and the Center for Astronomy (ZAH).

As mentioned in the previous section, there were also some special guided tours and lectures involving Institute management in 2011, which periodically take place on the occasion of visits by special guests. These included the Scientific Advisory Board and Board of Trustees, a visit by the governors of the University of Jerusalem (28 April), a group from the Olbers Society (6 May), a delegation from China (26 July), and the IMPRS Summer School (6 – 10 September). The Calar Alto Committee also met at the MPIA on 29 and 30 April. New ventures were the Visitor Colloquium on Monday afternoons and a regular Faculty Meeting. The Visitor Colloquium is reserved for especially qualified guest speakers to present scientific topics in an attractive way for scientists from all kinds of astronomical research fields. The faculty meeting is intended as a forum for information sharing and discussion among senior scientists, including the heads of the Research Groups, and is held about three times a year.

Aside from the Haus der Astronomie, other construction measures undertaken in 2010 included particularly the installation of a cleanroom air shower and completion of restoration of the façade.

Bereavements

Besides all these positive events, there was unfortunately cause for mourning. On January 1, the former director of the Calar Alto Observatory, Kurt Birkle, died due to a tragic traffic accident (see also Chapter V.7 of the 2009 Annual Report). And on July 22, Walter Rauh, the former head of MPIAs IT-Group and chairman of the works council, died after long illness. We will keep both in our thoughts.

Klaus Jäger, Thomas Henning,
Hans-Walter Rix, Markus Pössel,
Mathias Voss

V.2 Haus der Astronomie

The Haus der Astronomie, literally "House of Astronomy" (HdA), is Heidelberg's new center for astronomy education and outreach and to foster the exchange of knowledge between scientists. In 2010, the HdA continued its commissioning phase, commencing a number of its core activities.

The HdA's current, second year was off to a good start: With Markus Pössel (Managing scientist, financed by the MPG), Olaf Fischer (on secondment from the City of Heidelberg's Foundation for Youth and Science), Cecilia Scorza (temporary MPG position) and Jakob Staude (MPIA), the core team was almost complete. And after representatives of the HdA partners – the Klaus Tschira Foundation in charge of constructing the new building, the Max Planck Society, Heidelberg University and the City of Heidelberg – had participated in a festive breaking-of-the-ground ceremony in October 2009, construction of the center's spectacular galaxy-shaped building was going apace.

In spring 2010, there was a welcome addition to the HdA team: Carolin Liefke, previously a graduate student at Hamburger Sternwarte. Liefke's appointment is on secondment from the University of Heideberg; temporarily, it is financed jointly by the Baden-Württemberg State Ministry for Science, Research and the Arts and the Klaus Tschira Foundation. In fall, we were joined by a long-term intern, Marcel Frommelt, as part of the Federal Research Ministry's "Technikum" program. And as always, HdA operations were supported by colleagues from the MPIA, in particular managing director Thomas Henning, director Hans-Walter Rix, scientific coordinator Klaus Jäger, head of administration Mathias Voss, and Frank Witzel as representative of the technical services department.

The HdA mission is threefold: To communicate the fascination of astronomy to the general public, to support astronomy education, and to foster the exchange of knowledge between scientists.

Our outreach activities run the gamut from classical public relations to participation in large-scale public events.

Part of our outreach is done in our role as German node for the ESO Science Outreach Network, where our contributions include German translations of all ESO press releases (Liefke/Pössel). Another key part is participation in events for the general public. An example is our participation in "Explore Science" in June 2010, a five-day family science festival organized by the Klaus Tschira Foundation in Louisenpark in Mannheim, where we offered hands-on experiments and live (Solar) observing sessions.

Additional events this year included a joint public observing night (at Landessternwarte Heidelberg, in collaboration with Astronomieschule e.V.) on the occasion of Germany's national Astronomy Day in late April, participation in the Landessternwarte's events for National Monument Day in September, and, in mid-October, a booth with Solar science-themed activities at the Science Days held in one of Germany's largest theme parks, Europapark Rust (Scorza/Fischer/Liefke).

Both classical and new media are key partners when it comes to communicating astronomy to the public. That's why, in mid-November, we participated in the EU program ReLaTe ("Research Labs for Teaching Journalists") which offers research internships for journalists – in this case, two young Bulgarians learning about research into next generation telescopes at MPIA.

Our astronomy education flagship is the astronomical branch of the project "Wissenschaft in die Schulen!" (literally "Science into schools!", abbreviation: WIS!), in cooperation with the popular astronomy magazine Sterne und Weltraum. WIS! Astronomie, represented at HdA in the person of its editor and organizer Olaf Fischer, is all about transforming cutting-edge astronomy into classroom-ready curricular materials. To this end, Fischer and a team of WIS! authors – teachers and other educators as well as astronomers and other scientists – produce two sets of teachable materials per months, each directly linked to an article in the current issue of Sterne und Weltraum that reports on state-of-the-art astronomical research. The HdA's activities for WIS! are kindly supported by the Reiff Foundation for Amateur Astronomy. In early May, the authors of WIS! astronomy met at Spektrum der Wissenschaft Publishing House and at MPIA.

Hands-on experiments are one of the most direct ways of experiencing science. That's why "astronomy kits" – containing sets of simple experiments suitable for schoolchildren – are an important part of our educational outreach: Supported by funding from the MINT Box Project of Baden-Württemberg's State Foundation (Baden-Württemberg Stiftung), Cecilia Scorza and Marcel Frommelt developed and built "MINT boxes", astronomy kits for use in science teaching, with simple experiments from the field of infrared astronomy.

Our didactic materials are tested extensively during our events for school students and for teachers. In 2010, the infrared kits featured in student workshops at the LSW and at the Carl Friedrich High School in Mannheim, as well as in two teacher training sessions (the nation-wide teacher training in astronomy in Jena and a training session at Sonneberg Observatory; Fischer/Scorza). Additional teacher training sessions took place

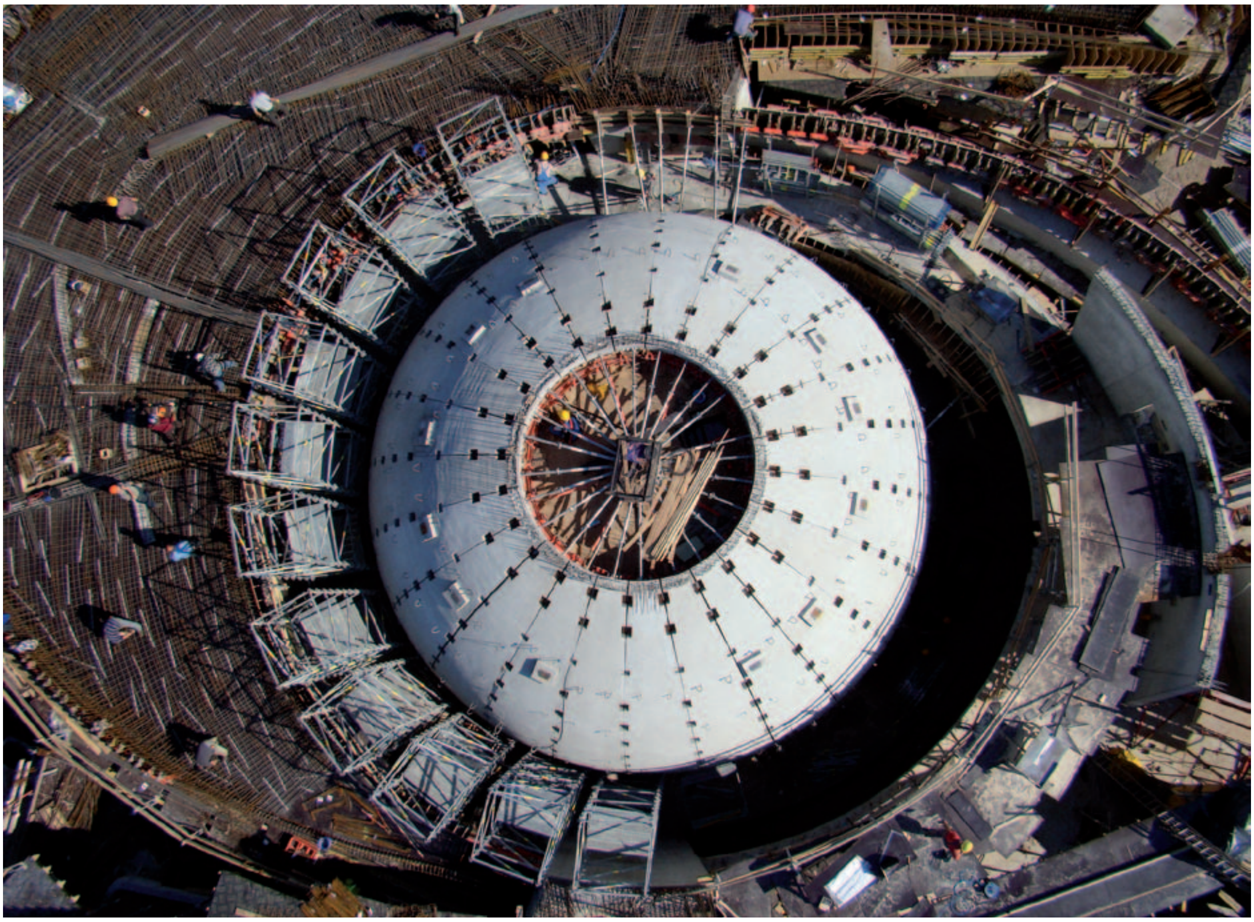


Fig. V.2.1: This overhead view shows the central dome of the Haus der Astronomie close to the topping out ceremony in autumn 2010.

at the Landesakademie Bad Wildbad (astronomy in science classes), on the occasion of the annual meeting of the German Astronomical Society (interferometry) and in cooperation with the German SOFIA Institute (training for SOFIA partner teachers; all of the above Scorza/Fischer). Of particular interest were a workshop aimed at kick-starting a network of teachers and amateur astronomers (Liefke) and two teacher training sessions in Chile as part of Heidelberg's "Centre of Excellence for Research and Teaching" in Santiago (Scorza/Fischer).

Other events for high-school students included a course on astro-spectroscopy at the Deutsche Schülerakademie in Rostock (Fischer) and a course "Let's go to Mars!" at the Science Academy Baden-Württemberg (Scorza/Fischer). HdA staff also contributed to MPIA's Girls' Day (Fischer/Liefke/Scorza/Pössel) and advised three BoGy interns (career orientation for high-school students; Fischer/Scorza).

In Summer, Olaf Fischer was made a lecturer (Privatdozent) at Heidelberg University's Faculty for Physics and Astronomy, strengthening the ties between the HdA and their university colleagues. This was also the first year we offered university courses for future physics teachers, namely one seminar each in summer term 2010 and winter term 2010/2011 (Fischer/Liefke/Scorza/Pössel). Olaf Fischer also served as advisor for a Staatsexamensarbeit (thesis work for students aspiring to become teachers) on the technical and scientific challenges of the SOFIA project, and how to integrate them into the high-school physics curriculum.

2010 was also the first year in which we actively offered, and participated in, student research projects. One example is the Pan-STARRS asteroid search in the framework of a collaboration between the International Astronomical Search Collaboration (IASC) and the Pan-STARRS project: high-school students looking for asteroids in Pan-STARRS image data, with a realistic chance of discovering previously unknown main-belt asteroids.

Some of our projects exploit the synergy between teaching university and high-school students. Case in point are two MPIA student research projects in which the HdA was involved (Liefke); these projects – exoplanet transit observations with the MPIA-HdA-50 cm telescope – were undergraduate projects in 2010, and have since evolved into projects for high-school students.

Student research was also part of our cooperation for the Hector-Seminar, an organization dedicated to fostering highly gifted high-school students. Over half a year, we helped Hector students to observe cloud structures on Jupiter, to simulate exoplanet transits and to use SDSS data to test the Hubble relation (Liefke and Pössel with J. Bouwman and A. van der Wel, MPIA). Previously, we had completed the SDSS-Hubble project with two students taking part in the International Summer Science School Heidelberg (Pössel with A. van der Wel, MPIA).

Also this year, Cecilia Scorza took a key step to improve our offerings for a younger audience in developing a concept for the German version of the "Universe Awareness" program (UNAWE) and (together with LSW director Andreas Quirrenbach) to join in with an EU proposal for UNAWE funds – an effort that was crowned with success.

This year, HdA staff members held 11 public talks for general audiences or for school students, e.g. in the framework of the Kinderuniversität ("Children's University") at Heidelberg University (Liefke).

For an institution such as the HdA, networking and cooperation with other major players in the field of astronomy education and outreach is very important. We organized and participated in a discussion forum "Astronomy and New Media" at the Forum Wissenschaftskommunikation in Mannheim, Germany's largest annual science communication conference (Pössel/Liefke) and had booths both at the "Market of Ideas" of Junge Universität Heidelberg and at Lernwelten 2010, a meeting on extra-curricular learning environments, in Hamburg. Furthermore, we presented HdA work and/or specific HdA projects in 8 specialist talks at meetings like the Global Hands-On Universe Conference in Munich (Pössel), "Public Outreach in Astronomy" at the annual conference of Astronomische Gesellschaft in Bonn (Pössel, Scorza) and at the "Communicating Astronomy with the Public" conference in Cape Town (Scorza).

Networking is all about people. In our case, Olaf Fischer is a member of the school commission of the German Astronomical Society, while Cecilia Scorza is the German coordinator of the European Association for Astronomy Education and the EUNAWE program, as well as a member of the IAU Commission on Education and Capacity Building (Commission 46).

Our third main area of activity, fostering the exchange between scientists, is the one which is most dependent on the completion of our future home; once completed, the galaxy-shaped new building will serve as the focus of all our activities – including the hosting of scientific meetings.

Construction itself, under the auspices of the Klaus Tschira Foundation, has been progressing quite impressively: The basic structure of the building, including the planetarium dome, made of pre-fabricated concrete, is finished, which fact was duly celebrated in a topping-off ceremony on December 17. Construction work on the interior continued all over the winter (see Fig. I.11).

The year 2010 has been a period of significant growth for the Haus der Astronomie – for the building as well as for the institution and its activities.

Markus Pössel, Olaf Fischer,
Carolin Liefke, Cecilia Scorza,
Jakob Staude, Thomas Henning,
Hans-Walter Rix, Klaus Jäger,
Mathias Voss, Frank Witzel

V.3 Honors and Awards

Sofja Kovalevskaja Award for Joseph Hennawi

Joseph Hennawi received one of Germany's most coveted prizes for science: one of the Sofja Kovalevskaja Awards of the Federal Ministry for Education and Research (BMBF), conferred by the Alexander von Humboldt Foundation every two years since 2002. After the Alexander von Humboldt professorship and the Leibniz Prize, it is Germany's most highly endowed research award; Joe Hennawi's prize money comes to 1.45 million Euro.

These awards are used by BMBF and the Foundation to promote research residencies of particularly highly qualified junior scientists from abroad at German research institutions or universities. The award was named after mathematician Sofja Kovalevskaja (1850 – 1891), the world's first female professor of mathematics. The research funds must be used for project work within six years. About a third of the prize-winners are German scientists who have been conducting research abroad; the prize aims to attract them back to Germany.

Joe Hennawi had recently joined Hans-Walter Rix's "Galaxies and Cosmology" department at the MPIA, and it is there that he will spend his Kovalevskaja-funded research residency, as head of a Research Group.

Hennawi's research programme covers questions about the age and the properties of the first stars and galaxies in the early universe and how they were formed billions of years ago at high redshifts. One particular method is the study of intergalactic gas using distant quasars, that is, the extremely bright cores of active galaxies at cosmological distances. By analysing the spectral lines in the quasar spectra that arise as the light from the quasars travels through intergalactic space on its way towards Earth, it is possible to study the gas at different redshifts and as a result temporal epochs, and compare it, for example, with the already measured large-scale structure of the universe (the "cosmic web"). In an extensive search, Joe Hennawi has identified extremely rare pairs of quasars with very small angular separation on the sky. This enables the comparative analysis of two adjacent lines of sight as described, as well as the identification of any subtle differences tangentially to the line of sight. The award was conferred by Annette Schavan, Federal Minister for Education and Research, and Helmut Schwarz, President of the Humboldt Society, at a ceremony in Berlin on 9 November.

Fig. V.3.1: Joe Hannawi (*center*) together with Annette Schavan and Helmut Schwarz during the award ceremony in Berlin.

Credit: Humboldt-Foundation / D. Ausserhofer

Further awards

The Ernst Patzer Prize was donated by the art-lover and philosopher Ernst Patzer and established by his widow. It is intended to support junior scientists.

The Foundation awards its prizes to young researchers at the MPIA and other institutes in Heidelberg and wishes to support science and research particularly in the field of astronomy.

The annually presented prizes are honouring the best publications produced in the course of doctoral studies or in the following postdoc phase. The publications must have been published in a refereed journal. The selection committee consists of two scientists from MPIA and one additional external scientist from Heidelberg.

This year's prize winners were:

- **Sarah Martell**, for her paper "Light-element abundance variations in the Milky Way halo (2010, Astronomy & Astrophysics 519, A14),
- **Jouni Kainulainen**, for his publication "Probing the evolution of molecular cloud structure: From quiescence to birth" (2009, Astronomy & Astrophysics 508, L35),
- **Andras Zsom** for his paper "The outcome of protoplanetary dust growth: pebbles, boulders, or planetesimals? II. Introducing the bouncing barrier (2010, Astronomy & Astrophysics 513, A57).

As in recent years, they were honored during the Patzer Colloquium which took place on December 3rd in the lecture hall of the MPIA where the prize winners gave an half an hour presentation of their work.

For his pioneering research on dark matter halos of galaxies, **Surhud More** received the **Otto Hahn Medal** of the Max-Planck-Society for outstanding achievements of young scientists.

Marc-André Besel won the Max Planck Research Group Award of the Max Planck Society and David Martinez Delgado received the Humboldt Fellowship for Advanced Research.

Christiaan Ormel received the "Van Swinderenprijs" of the Royal Natuurkundig Genootschap Groningen (KNG) of the Dutch Physical Society for the best doctoral thesis of the year 2008.

Furthermore, Hans-Walter Rix was entrusted with the Emilio Segre Lectureship and the John Bahcall Lectureship.

Klaus Jäger

V.4 "Simulations have today become the third pillar of science"

An interview with Volker Springel from the Heidelberg Institute for Theoretical Studies (HITS) about the importance of simulations for astronomy, the use of visualisations for education and public outreach work, and his reasons for moving from Garching to Heidelberg.

K. J.: *In 1972, the Toomre brothers published the first very impressive numerical simulations of galaxy interactions. One of their examples was the well-known spiral galaxy M 51, which served as a model for the "Haus der Astronomie" (lit. House of Astronomy) we will come to shortly. How important were those first simulations for astronomy?*

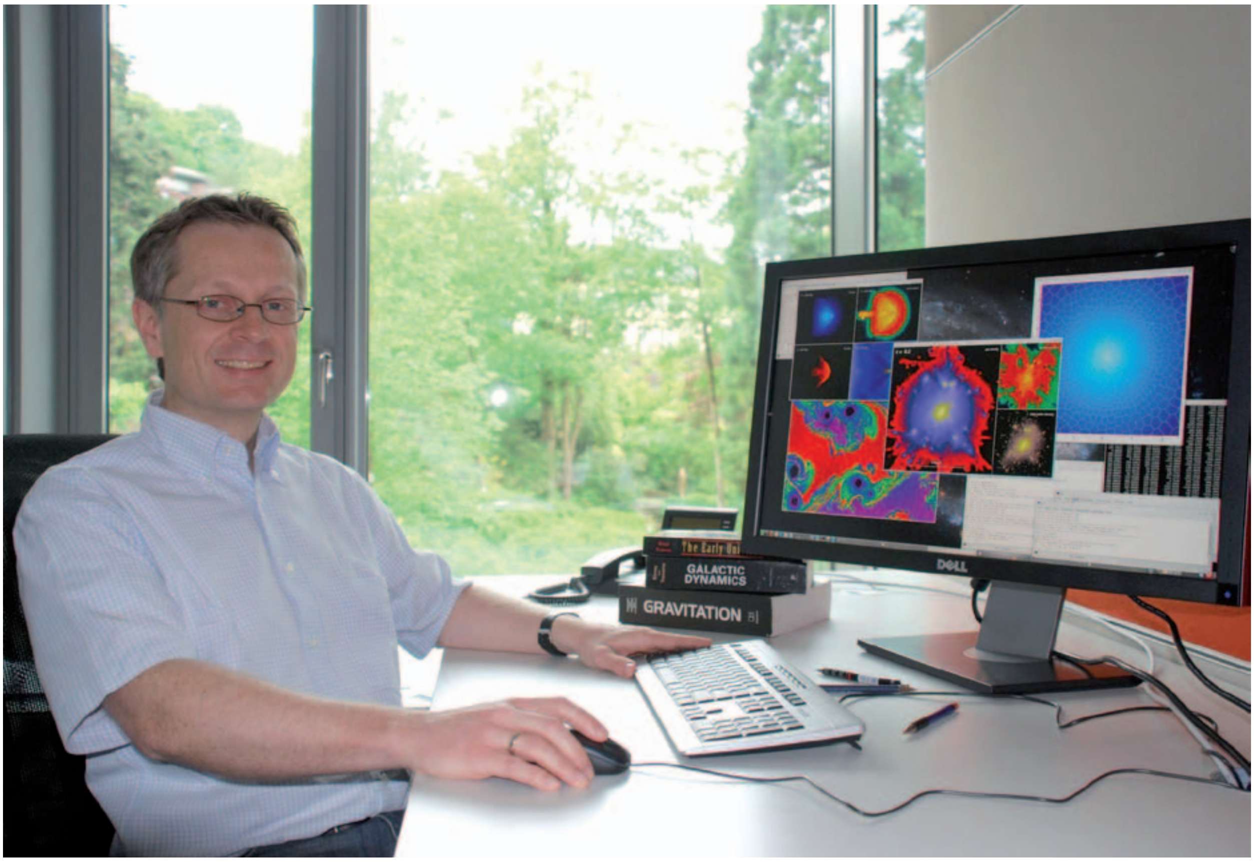
Volker Springel: I think it was a truly defining moment for astronomy and astrophysics. The Toomre simulations suddenly revealed a process lasting billions of years to the direct scrutiny of scientists. These made it possible to graphically demonstrate and reconstruct the plausible hypothesis that two galaxies can actually merge and form a new galaxy. This is also true of the tidal arms and other structures we see around such galaxies today. The hypothesis that these peculiar galaxy pairs are in the process of merging was a very daring one at the time, and met with a large degree of scepticism. It's a good example of how a theorist's hypothesis can be confirmed, and even more so when you look at the modern versions of such simulations that are available today. The STScI, for instance, has a wonderful film that shows a single simulated galaxy collision, and the film is stopped at different stages and overlaid with HST images of real galaxy pairs. The similarity is so astonishing that you simply have to believe the merger hypothesis once you've seen the film.

K. J.: *The Toomre brothers also came up with the idea that elliptical galaxies are the result of spiral galaxy mergers …*

Volker Springel: That's right. To the best of my knowledge, many astronomers dismissed the idea as absurd at the time, even though Toomre's calculations were already very convincing, in my opinion. But it took quite a long time for the scientific community to be convinced.

K. J.: *What is the importance of numerical simulations in astrophysics and physics today? Is their role in astron-*

Fig. V.4.1: Volker Springel in his office at the HITS.



Credit: HITS

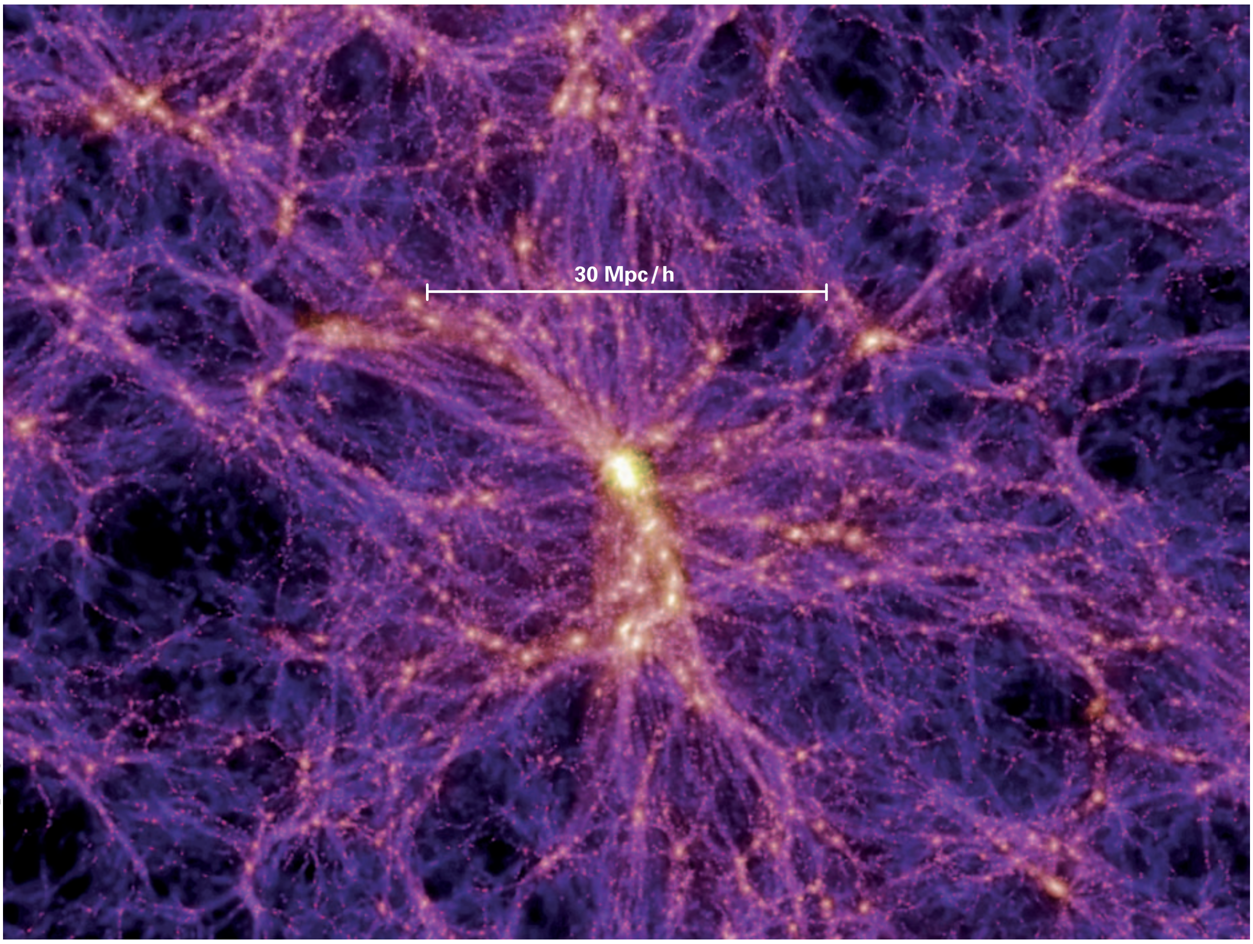
omy more important than in other fields? Are computers just faster and able to work with more particles, for example, or have there been fundamentally new developments? What has changed since those times?

Volker Springel: I think their importance has increased considerably; we could even describe the development as breathtaking. It's sometimes said that simulations have become the third pillar of science, along with conventional astronomical observations and experiments in physics and traditional theory. I believe this is especially true of astronomy, because we hardly ever have the chance to conduct normal experiments. With simulations, however, we can now do just that in a way; that is, we can conduct experiments on the computer. For example, I can check what happens in a galaxy cluster if I switch on thermal conduction, or if a black hole fires a jet into the intergalactic medium. Or we can run simulations of two merging galaxies taking account of the massive central black holes, which were still unknown back then; or how quasars are stimulated to emit light by such a process, or how long black holes take to merge, and so on. These are all questions that generally can't be answered using analytical calculations. In other words, simulations constitute a method for numerically solving complex equation systems that cannot be solved by other means. They are calculations of evolution through time that are constantly becoming faster and more accurate. We benefit from the fact that computers double in efficiency about every year and a half. Many conventional physicists initially doubted whether this was really true, reliable science, but simulations have now found their way into the mainstream of astrophysics and are recognised as an important scientific technique.

K. J.: *What are today's major challenges, the key issues? Dark matter and dark energy? What lies ahead?*

Volker Springel: I see challenges for simulations in two major areas. First of all, you have the cosmological questions that have to do with the matter and energy content of the universe, and particularly with the dark side of the universe. The standard model of cosmology makes a very daring hypothesis, which is that the postulated cold dark matter (CDM) consists of a yet unknown elementary particle.

Fig. V.4.2: A snapshot of the famous Millennium Simulation mentioned in the interview. It traces the matter distribution in a cubic region of the universe. The marked scale of 30 Mpc corresponds to about 100 million lightyears.



Credit: Volker Springel

Simulations were very successful in this area because they enabled predictions relating to the appearance of non-linear structures, and because they first allowed verification of whether CDM could actually be a feasible world model. And the current answer is that it looks very promising – at least on large scales. At smaller scales, however, we don't quite know yet whether the structures, as we see them in our own galaxy, for example, do really conform to this hypothesis.

There is currently a very intense ongoing debate about whether it will only take better, more precise simulations, that is, ultimately more powerful computers, to resolve apparent existing discrepancies, such as the rotational speeds at the centre of galaxies.

The computations are a powerful tool, because they link the simple status of the universe shortly after the big bang with its complexity today. If the cosmological theory is correct, we should be able to use the very precise known starting conditions to accurately calculate the kind of structures we see in the present-day universe. If it doesn't work, the theory is wrong. Carrying out this test is one of the major challenges.

The other is understanding the astrophysics of individual objects, such as galaxies and planets, where a great deal of complex physics is not understood in detail. Magnetic fields, incredibly wide density ranges, nuclear physics, radiative transfer – all these play important roles. The relevant physical equations are known, but that doesn't mean we understand the complex interactions described by them. For example, what regulates star formation in a galaxy? I expect that simulations will provide more and more detailed depictions of these physical processes, thereby enabling theoretical advances.

K. J.: *Would you also find it interesting to work in the field of planet formation? I am thinking, for instance, of the question of how larger structures and even planets can be formed from many small particles.*

Volker Springel: Yes, I find that quite fascinating and I would be happy to do more work in that area, but there is still plenty to do in my own field. However, I am already working with colleagues at the Max Planck Institute for Astronomy (MPIA) and the Heidelberg Centre for Astronomy (ZAH) on some smaller projects related to protoplanetary disks, although these processes are happening on a much smaller scales than those in my main area of specialisation.

K. J.: *If you have these physical differences, do colleagues tend to discuss then in particular about their methodology?*

Volker Springel: Yes, methodological and technical issues provide an important first point of connection. For example, how do I simulate a mixture of gas and dust? This is of interest in relation to both protoplanetary disks and galaxies. However, I see myself primarily as an astrophysicist and would actually like to deal less with numerical and technical issues. On the other hand, they are an important precondition for simulations in the first place.

K. J.: *What was the clincher that made you move towards simulations instead of, say, observational astronomy? Was it planned or just coincidence? And how did you choose astronomy in the first place?*

Volker Springel: It was clear to me during my last few years in secondary school that I wanted to study physics. I also thoroughly enjoyed taking part in a school competition, the Physics Olympiad. At first, I was interested in particle physics and high energy physics. But then I attended lectures in cosmology and found it so fascinating that I continued along in that direction. I wasn't that interested in observations, but very much so in simulations. I had also taken part with my first simulation in the "Jugend Forscht" young scientists competition – that was related to chaos physics. Later, I was able to convince Simon White to let me use simulations for my doctorate. A nice aspect of simulations is that I am in charge of my own data. I can generate it myself, and I'm not necessarily subject to the political constraints of major collaborations. I had some negative experiences in this area during my thesis research, when I was not allowed to use certain findings because they had already been "assigned" elsewhere. With simulations, you can achieve a lot in small groups or even alone, and there is less politics involved. I found that very appealing.

K. J.: *Since 2010, you are working at the Heidelberg Institute for Theoretical Studies (HITS), an institute devoted to the interpretation of data through the development of new theoretical approaches. It is anything but a pure astronomy institute, setti ng great store by interdisciplinarity. I am sure that the conditions at the Max Planck Institute for Astrophysics in Garching were not bad, so what induced you to move here? Was it the allure of multidisciplinary cooperation? And what kind of bridges exist between, say, molecular or cellular modelling and astronomy?*

Volker Springel: Yes, the conditions at the MPA and in the Max Planck Society in general were fantastic, and I look back on that period fondly. On the other hand, as a group leader my independence was somewhat limited, and in that context I found the offer of a professorship in Heidelberg very attractive. Of course, other factors included the city itself and the impressive academic environment, particularly in astronomy, because together with Garching and Bonn, Heidelberg has to be considered Germany's main location for astronomy, with great international visibility. It also has unique selling points, such as the soon-to-be-opened Haus der Astronomie, which I think is a truly fantastic development. But the offer of really building up a group based on my own ideas at HITS was particularly appealing.

HITS is a multidisciplinary institute. I prefer the term "multidisciplinarity" as compared to that of "interdisciplinarity". We have a variety of natural scientists who generally work in fields of data-driven research, and this is the focus that holds HITS together, so to speak.

It is the wish of Klaus Tschira, the generous founder of HITS, that the institute embraces a broad spectrum of subjects. This makes everyday work very interesting. HITS represents a wide range of fields, but our methods often overlap as, for instance, with the molecular dynamics simulations used in biology and the SPH simulations of cosmic gases. We also share a very powerful mainframe computer in HITS, which is generously financed by the foundation. Our technical facilities are very good, similar to those of the Max Planck institutes. Some HITS group leaders, myself included, also hold professorships at the university. I am a member of the faculty of physics and astronomy and thus have good contacts to students as a result of my teaching activities. The only downside I see is that the astronomy institutes in Heidelberg are so scattered. Even though we hold joint events, it really is a bit hard sometimes to meet a colleague from another institute quickly and spontaneously on short notice. Nevertheless, I feel well connected to the other researchers in Heidelberg in the Centre for Astronomy (in particular through the collaborative research center "Milky Way"), the Institute for Theoretical Physics (Transregio "The Dark Universe"), and of course in the Max Planck Institute for Astronomy. At the MPIA, for example, I often meet Andrea Maccio and Joe Hennawi. We have a joint weekly seminar between my group and the MPIA cosmologists.

K. J.: *You have mentioned the Haus der Astronomie, and I would like to discuss the whole aspect of public outreach work. You are well known for your work on the Millennium Simulation, and it is frequently portrayed in the media because it is so spectacular. How important are visualisations like these for public outreach?*

Volker Springel: Astronomy seems to excite practically everyone's curiosity, not only that of the specialists. It fascinates people by trying to answer fundamental questions of human existence, such as "Where do we come from?", "What is our place in the cosmos?", and so on. Since astronomy research does not necessarily deliver results with immediate economic benefits, but instead corresponds more to pure research, the financial costs must be seen mainly as a cultural expense. It appears that the public at large also sees it this way, as these outlays are hardly ever called into question. The way I see it, we have clearly a duty to present our findings to the public and satisfy their curiosity and interest. Besides, unlike other fields of basic research, astronomy produces a lot of visually engaging material: just think of the awe-inspiring images from astronomical observations. But today, thanks to computer simulations, we can also visualise and show phenomena that can't be perceived through our normal senses or physical detectors. This includes time lapse films that show the 13.7 billion-year history of the universe in 2 minutes, as well as visualisations of dark matter. Indeed, the Millennium Simulation is shown repeatedly because it is very aesthetically appealing, too. A lot of work went into the visualisation to achieve that result, but all the same, I hadn't really anticipated that level of success. It made the scientific field widely known not only among the public, but also in academic circles, and I find it very gratifying when colleagues use visual material from the simulation for introductory lectures. It was a worthwhile piece of work. Besides, these kinds of visualisations help scientists themselves to get a better idea of the relevant processes. You need images in front of your eyes and in your head in order to gain an intuitive understanding of, say, the relationship between visible and dark matter. In the case of the Millennium simulation, it started out as just a gigantic list of numbers – about 500 billion of them – but such a pile of numbers on its own doesn't help us to understand the physics behind it.

K. J.: *We'll be opening the Haus der Astronomie at the end of 2011. It is intended as a unique centre for scientific exchange, public relations work and education in astronomy, building on the numerous existing public outreach activities of the MPIA and the other Heidelberg-based institutes. One of our aspirations is to use and, indeed, create more of these visualisations to these ends. What do you expect from the Haus der Astronomie? Are you interested in some kind of cooperation?*

Volker Springel: I think the Haus der Astronomie will provide a forum for professionalising the astronomy outreach of all institutes here in Heidelberg and beyond, so that the general public will be even more enthusiastic, and more teachers and schoolchildren, and indeed students, will come to Heidelberg. I believe it is a very important boost for the support of junior scientists in our field, as well as for established scientists, because we will also hold scientific meetings there. Moreover, it is bound to be very appealing for colleagues from other places to come to the Haus der Astronomie. Together with A. Maccio of the MPIA, I am planning a conference on disk galaxies soon after the inauguration of the building. And of course it will be very inspiring to hold the meeting in a building that itself has the shape of a spiral galaxy. What's more, the modern projection system in the domed auditorium will enable us to show our simulations in unprecedented quality. In general, I imagine that students who visit the Haus der Astronomie will leave with a feeling of great enthusiasm and incredible motivation to conduct research. Everyone knows that science is hard work; but when the results are properly communicated, it makes a huge difference to motivation levels.

I also expect that the Haus der Astronomie will get colleagues thinking about the best way to present the results of their own research – both to one another, and to the general public.

K. J.: *Thank you for your time.*

The Interview was conducted by Klaus Jäger.

Prof. Dr. Volker Springel
was born in 1970. He studied physics at the University of Tübingen and at the University of California at Berkeley. He made his doctor's degree in the year 2000 at the Ludwig Maximilians University in Munich, whereas he carried out his doctoral research at the Max Planck Institute for Astrophysics (MPA) in Garching in the department of Prof. Simon White.

After postdoctoral work at Harvard University and at the MPA, he became tenured and led a research group for numerical cosmology at the MPA between 2005 and 2010.

Since 2010 he is Research Group Leader at the newly founded Heidelberg Institute for Theoretical Studies (HITS), which is financed by the Klaus Tschira Foundation (KTS) in Heidelberg. Furthermore, he is now also Professor of Theoretical Astrophysics at the University of Heidelberg.

Volker Springel received several awards, including the Otto-Hahn Medal by the Max-Planck-Society in 2000, the Heinz Maier-Leibnitz Prize of the German Science Foundation (DFG) in 2004, the International Media Award for Science and Art in 2005, and the Klung-Wilhelmy-Weberbank Prize for Physics in 2009.

He is member of the Young Academy at the Berlin-Brandenburg Academy of Sciences and Humanities (Berlin-Brandenburgische Akademie der Wissenschaften – BBAW) and the German Academy of Natural Scientists Leopoldina (Deutsche Akademie der Naturforscher Leopoldina).

His main research interests are the formation and evolution of galaxies, the large-scale structure in the Universe, dark matter and dark energy, computational astrophysics, supermassive black holes and their influence on galaxies, cosmology, star formation and its regulation, clusters of galaxies, the Milky Way galaxy, intergalactic medium, chemical enrichment, and non-standard cosmological models.

Staff

Directors: Henning (Managing Director), Rix

Scientific Coordinator: Jäger
Public Outreach (Head),
Haus der Astronomie (Managing Scientist): Pössel
Administration: Voss (Head)
MPIA Observatories: Gredel

Scientists: Afonso, Bailer-Jones, Balog, Bertram, Beuther, Birnstiel (since 20.10.) Borelli, Bouwman, Brandner, De Bonis, De Jong (until 31.3.), Dullemond, Dumas, Dziourkevich, Feldt, Fendt, Fried, Gallazzi (until 30.9.), Gässler, Goldman, Goto, Gouliermis, Graser, Gredel, Hennawi, Herbst, Hippler, Hofferbert, Inskip, Huisken, C. Jäger (until 31.1.), K. Jäger, Jahnke, Joergens, Kaltenegger (since 1.9.), Klaas, Klahr, Klement, Köhler, Krause, Kürster, Launhardt, Leipski, Lenzen, Linz, Macciò (since 1.10.), Marien, Martin, Meisenheimer, Möller-Nilsson, F. Müller, Mundt, Nielbock, Pavlov, Peter, Petitdemange (since 1.7.), Pössel, Pott, Rodriguez, Sandor, Sargent, Scheithauer, Schmiedeke (since 1.10.), Schinnerer, Schreiber, Semenov, Setiawan, Sicilia–Aguilar, K. Smith, Stilz, Stumpf (until 31.10.), Trowitzsch, Tsalmantza, van Boekel, van de Ven, Walter

Postdocs: Benisty (since 1.10.), Bik, Biller (since 15.9.), Bonnefoy (since 15.11.), Carpentier (1.2.–31.7.), Carson (until 30.6.), Commerçon, Crighton (since 15.10.), Decarli, Doellinger (since 1.9.), Gielen (since 1.9.), Groves (since 1.11.), Hatt (since 24.9.), Hodge (since 1.10.), Kainulainen, Kendrew (since 15.10.), Hua-Bai Li, Macciò, (until 30.9.), Lyubenova (since 15.5.), Martinez-Delgado, Meidt, Mordasini, Morganson, Noel, Olofsson, Olczak, (1.3.–30.9.), Ormel, Pasquali (until 30.6.), Perryman, Ragan, Rubin (since 15.9.), Sandstrom, Stutz, Thalmann, Tremonti (bis 19.7.), Turner (until 28.2.), R. van den Bosch, van der Wel, Vasyunin (until 31.8.), Wei Wang (until 31.8.), Watkins (since 1.9.), C. Wolf (until 30.9.), Yang, Zhukovska, Zibetti (until 31.8.)

PhD Students: Doktoranden: Albertsson (since 1.9.), Bergfors, Besel, Birnstiel (until 19.10.), Boley, Brasseur, Burtscher, Chang (since 1.9.), Chen Guo (since 1.9.), Cisternas, Cologna (since 15.7.), Colombo (since 15.6.2010), Crnojevic (until 9.12.), Csak, Da Rio, De Rosa, Dittrich (since 15.7.), Dopcke, Fallscheer (until 31.5.), Min Fang, Federrath (until 31.3.), Flock, Follert, Foyle, Gennaro, Golubov, Grootes, Holmes, Hormuth (until 31.10.), M. Jäger, Johnston (since 1.11.), Juhasz (until 31.3.), Kalinova (since 15.10.), Kannan (since 1.7.), Karim, Kern (until 31.3.), Kudryavtseva, Külebi, Kuiper (until 30.4.), Läsker (since 1.9.), Lefa (30.6.), Fan Liu, Lei Liu (since 1.10.), Lippok (since 1.9.), Chia-Chun Lu, Lütjohann (1.9.–30.11.), Ludwig, Maier (since 1.6.), Meyer, Mohler (since 1.9.), Moster (bis 30.11.), Moyano, Natale (until 14.5.), Nikolic (since 1.10.), Nikolov, Nugrohu, Pinilla, Pitann, Potrick, Porth, Raettig, Ramkumar (since 1.7.), Robaina (until 15.7.), Roccatagliata (until 30.4.), Rochau, Ruhland, Rodriguez-Ledesma, Sabri, Schmalzl, K. B. Schmidt, T. Schmidt, Schruba, Schulze-Hartung, Skelton (until 15.7.), Steglich, Sturm, Tackenberg, Trifonof, Uribe, Ueltzhöffer (until 30.9.), Valente, van der Laan, Vasyunina, Hsiang-Hsu Wang, Yuan Wang (until 31.8.), Weise, Windmark (since 1.9.) Zechmeister, Lan Zhang (since 1.9.), Miaomiao Zhang (since 1.9.), Xianyu Zhang (until 31.10.), Zhao-Geisler (until 30.6.), Zsom

Diploma Students and Student Assistants (UH): Ahmad (1.5.–31.10.), Barboza (since 1.9.), Bideaux (until 28.02), Dittkrist, Fiedler, Morrison (since 1.5.), Panduro (since 15.10.), Schewtschenko (until 31.03), Schmiedeke (until 31.7.), Schneider (since 13.12.), Schnupp, Wylezalek (until 31.7.)

Diploma and Master Students (FH): Bideaux (until 28.2.), Blanco (until 28.2.), Däschner (1.3.–31.8.), Neumeier (since 1.9.), Niemann (since 1.9.)

Interns: Abel, Baldauf (since 1.9.), Betzold (since 1.4.), Blanco (until 28.2.), Brezinski, Christmann (until 31.7.), Däschner (1.3.–31.8.), Ehret, Euler (since 1.9.), Fastner (until 28.2.), Hoppe (since 23.8.), Jentsch (since 15.10.), Kugler (since 1.9.), Lechner, Merx (until 28.2.), Neidig, Neumeier (since 1.9.), Niemann (since 1.9.), Pfeiffer (until 31.7.), Wegle (1.3.– 31.8.), Wipfler

Public Outreach / Haus der Astronomie: Pössel (Head), Fischer, Liefke, Quetz, Scorza; Trainee: Frommelt (since 1.9.)

Technical Departments: Kürster (Head)
Mechanics Design: Rohloff (Head), Baumeister (Deputy), Ebert, Huber, Münch, Schönherr; trainees, interns, student assistants: Barboza (since 1.9.), Euler (since 1.9.)

Precision Mechanics Workshop: Böhm (Head), W. Sauer (Deputy), Heitz, Maurer, Meister, Meixner, Merx (1.3.–31.8.), Stadler; trainees, interns, student assistants: Abel, Baldauf (since 1.9.), Brezinski, Christmann (until 31.07.), Ehret, Hoppe (23.8.–15.10.), Kugler (since 1.9.), Merx (until 28.2.), Neidig, Wipfler

Electronics: Wagner (Head); Mohr (Deputy); Adler, Alter, Bieler Ehret, Klein, Lehmitz, Mall, Mohr, Ramos, Ridinger, Wrhel; trainees, interns, student assistants: Bideaux (until 28.2.), Blanco (until 28.2.), Däschner (1.3.–31.8.), Jentsch (since 15.10.), Fastner (until 28.2.), Niemann (since 1.9.), Neumeier (since 1.9.), Wegle (1.3.–31.8.)

Instrumentations-Software: Briegel (Head); Storz (Deputy), Berwein, Borelli, Kittmann (guest from Universität Köln), Kulas (since 1.6.), Möller-Nilsson, Neumann, Pavlov, Trowitzsch; trainees, interns, student assistants: Panduro (15.10.), Pfeiffer (until 31.7.)

Engineering and Project Management: Marien (Head), Bizenberger (Deputy), Bertram, Blümchen, Brix, De Bonis (guest from Universität Köln), Gässler, Graser, Laun, Mellein (since 1.6.), Meschke, Naranjo, Peter

Administrative and Technical Service Departments:

Administration: Voss (Head); purchasing dept.: Wolf (since 1.4.) Heißler (until 31.8.), Anders; finances dept.: S. Schmidt, Anders, Enkler, Zähringer; staff dept.: Apfel, Baier, Hölscher, Scheerer, Schleich; reception: Beckmann; trainees: Lechner

Library: Dueck

Data Processing: Richter (Head), Piroth (Deputy), Hiller; Student Assistant: Fiedler

Photographic Lab: Anders

Graphic Artwork: Quetz (Head), Meißner, Müllerthann

Secretaries: Bohm, Janssen-Bennynck, Koltes-Al-Zoubi, Seifert, Witte-Nguy

Technical Services and Cafeteria: Zergiebel (Head until 31.7.), F. Witzel (Head since 1.8., Deputy until 31.7.), Behnke, Drescher, Heller (since 1.5.), Jung, Lang, Nauss, B. Witzel, E. Zimmermann

Former Staff Members Acting for the Institute: Christoph Leinert, Dietrich Lemke, Jakob Staude

Guests: Kerstin Meyer-Ross, 28.–30. Jan.; Clare Dobbs, MPE, 28.–29. Jan.; Bill Sweeney, IfA, 24.–29. Jan.; Molly Peeples, Ohio State Univ., 24.–28. Jan.; Takashi Hosokawa, NAO, 17.–30. Jan.; Zakaria Meliani, Centre Plas. Astrophys., 1.–5. Feb.; Giovanna Tinetti, Univ. College London, 1.–5. Feb.; Eric Emsellem, ESO, 2.–3. Feb.; Ric Davies, MPE, 2.–3. Feb.; Marie Martig, CEA Saclay, 2.–6. Feb.; Myriam Benisty, INAF, 1. Feb.; Hendrik Hildebrandt, Observatory Leiden, 8.–9. Feb.; Date Rubin, UCSC, 8.–10. Feb.; Jackie Radigan, Univ. Toronto, 8.–10. Feb.; Beth Biller, IfA Hawaii, 9.–14. Feb.; Tobias Kaufmann, ETH Zürich, 9.–12. Feb.; Rob Detmers, SRON Utrecht, 11.–12. Feb.; Gijs Mulders, Univ. Amsterdam, 8.–20. Feb.; Dusan Keres, Harvard Smithsonian, 16.–19. Feb.; Laura Watkins, Cambridge Institute, 18.–20. Feb.; Mariya Lyubenova, ESO, 23.–24. Feb.; Tobias Albertsson, Lund Univ., 24.–26. Feb.; Riccardo Smareglia, INAF, 21.–27. Feb.; Tijl Verhoelst, Sterrewacht Leuven, 22.–26. Feb.; Mickael Bonnefoy, Observatory Grenoble, 22.–27. Feb.; Juan Carlos Munoz, AIP, 22.–26. Feb.; Frank Bigiel, Berkeley, 22.–26. Feb.; Eric Rosolowsky, Univ. British Columbia, 22.–26. Feb.; Axel Weiss, MPIfR Bonn, 22.–26. Feb.; Neil Crighton, Durham, 28. Feb.–2. March; Neal Turner, JPL/Caltech, 3. Nov. 2009.–25. Feb. 2010; Tristen Hayfield, ETH Zürich, 1.–5. March; Maryam Habibi, Univ. Köln, 2.–5. March; Andrea Stolte, Univ. Köln, 2.–5. March; Benjamin Hussmann, Univ. Köln, 3.–5. March; Ilse De Looze, Univ. Gent, 3.–5. March; Maria Khramtsova, Ural State Univ., 21. Feb.–14. March; Isa Oliveira, Observatory Leiden, 1.–12. March; Jason X. Prochaska, UCSC/UCO Lick, 8.–12. March; Jorge Pen-arrubia, Cambridge Univ., 9.–13. March; Nikoletta Sipos, Konkoly Univ., 10.–12. March; Andrey Sobolev, Ural State Univ., 17. Feb.–17. March; Marijn Franx, Observatory Leiden, 16.–18. March; Christian Wolf, 16. Nov.–31. March; Ronald Laesker, Univ. Victoria, 4. Jan.–31. March; Marco Spaans, Univ. Groningen, 1. Apr.; Matt Bayliss, Univ. Chicago, 5.–10. Apr.; Olja Panic, ESO Garching, 7.–9. Apr.; Lan Zhang, NAO, 18. Jan.–15. Apr.; Nikolai Voshchinnikov, State Univ. St. Petersburg, 18. March–15. Apr.; Alexander Hubbard, Nord. Institut Stockholm, 11.–15. Apr.; Paul Westoby, Liverpool Univ., 13.–17. Apr.; Mansur Ibrahimov, Madidansk Observatory, 20.–27. Apr.; Karsten Dittrich, Univ. Rostock, 26.–27. Apr.; Zsolt Regaly, Konkoly Observatory, 19.–29. Apr.; Michaela Doellinger, ESO, 18.–19. Apr.; Patrice Okouma, Univ. Cape Town, 3.–7. May; André Mueller, MPIA/ESO, 3.–12. May; Massimo Dotti, MPE Garching, 8.–14. May; Paola Pinilla, Bogota, 12.–14. May; Kerstin Geißler, State Univ. NY, 12.–14. May; Davide Fedele, Johns Hopkins Univ., 27. Apr.–6. May.; Steve Boudreault, Stony Brook Univ., 1.–6. May; Vincenzo Antonuccio-Delogu, INAF, 15.–20. May; Alessandro Ederoclite, Instituto de Astrofísica de Canarias, 8.–23. May; Guy Perrin, IAP Paris, 17.–19. May; Luciano Casarini, Univ. Milano, 17.–26. May; Michele Fumagalli, UCSC, 24.–28. May; Sebastian Egner, Univ. Hawaii, 26.–28. May; Andrew Dolphin, Raytheon Company, 22.–31. May; Sarah Kendrew, Sterrewacht Leiden, 31. May.–1. June; Jose Caballero, Univ. Madrid, 1.–3. June; Nikoletta Sipos, Konkoly Observatory, 16. May.–12. June; Erwin De Blok, Univ. Cape Town, 27. May.–10. June; Peter Abraham, Konkoly Observatory, 3.–12. June; Agnes Kospal, Konkoly Observatory, 3.–12. June; Doug Johnstone, Herzberg Institute, 7.–14. June; Alan Hulsebus, Iowa State Univ., 7.–11. June; Massimo Marengo, Iowa State Univ., 7.–11. June; Fabian Heitsch, Univ. Michigan, 7.–13. June; Kengo Tomida, NAOJ, 7.–13. June; Fumitaka Nakamura, Niigata Univ., 7.–13. June; Andrea Stolte, Univ. Köln, 7.–9. June; Benjamin Hussmann, Univ. Köln, 7.–9. June; Taylor Bourke, Harvard Smithsonian, 10.–13. June; Maryam Habibi, Univ. Köln, 7.–9. June; Robert O'Dell, Vanderbilt, 18.–24. June; Doug Johnstone, Herzberg Institute, 18.–22. June; Ray

Jayawardhana, Univ. Toronto, 20.–23. June; Rom Megeath, Univ. Toledo, 21.–23. June; Jo Bovy, Center for Cosmology NYU, 21. June–21. Aug.; Balasubramanian Ramkumar, 14. Jan.–15. July; Romain Vuillez, l'Ecole Polytechnique Paris, 22. Apr.–19. July; Zsolt Regaly, Konkoly Observatory, 16. June–15. July; Christi Tremonti, Univ. Wisconsin, 24. June–15. July; Julianne Dalcanton, Univ. Washington, 23. June–19. July; V. Kalinova Dimitrova, 18.–19. July; Benjamin Weiner, Steward Observatory, 28. June–23. July; Ranjan Gupta, IUCAA Pune, 7.–10. July; Bradley Frank, Univ. Cape Town, 9.–20. July; Warrick Lawson, Univ. New S. Wales, 13.–23. July; Laura Schreiber, INAF Bologna, 12.–23. July; Emiliano Diolaiti, INAF Bologna, 19.–23. July; Xiaohui Fan, Steward Observatory, 22.–24. July; Martin Weickgenannt, Institut für Sytemdynamik, 22. July; Thomas Ruppel, Institut für Sytemdynamik, 22.–24. July; Tilman Pfeiffer, 4. May.–31. July; Erwin De Blok, Univ. Cape Town, 1.–28. July; Greg Rudnick, Univ. Kansas, 1.–31. July; Bronson Wacker, Univ. Kansas, 8.–30. July; Adrian Price-Whelan, NYU, 26.–30. July; Aukosh Jagannath, NYU, 26.–30. July; Jessica Ruprecht, MIT, 7. June–30. Aug.; Marion Dierickx, Harvard Univ., 8. June–30. July; David Hogg, NYU, 1. July–31. Aug.; Elisa Schroeder, 6. July–6. Aug.; Adam Myers, Univ. Illinois, 7. July–21. Aug.; Mark Swain, JPL, 25. July–29. Aug.; Gabor Worseck, UCSC, 1.–6. Aug.; Aldo Dall'Aglio, AIP, 2.–6. Aug.; Sabine Graf, Univ. Kaiserslautern, 2.–13. Aug.; Kambiz Fathi, Stockholm Univ., 3.–6. Aug.; Colin McNally, American Museum of Natural History, 3.–30. Aug.; Frank Bigiel, Berkeley, 12.–13. Aug.; Wladimir Lyra, American Museum of Natural History, 8.–22. Aug.; Bradford Holden, Univ. California, 14.–27. Aug.; Daniel Angerhausen, Univ. Stuttgart, 14.–16. Aug.; Sergey Koposov, Univ. Cambridge, 20.–29. Aug.; Lucas Ellerbroek, Univ. Amsterdam, 23.–27. Aug.; Willy Benz, Univ. Bern, 23.–24. Aug.; Helen Morrison, 1. March–31. Aug.; Nisha Katyal, IUCAA Pune, 29. July–1. Sep.; Michael Maseda, Caltech, 12. June–4. Sep.; Mordecai-Mark Mac Low, American Museum of Natural History, 2. Aug.–4. Sep.; Hanno Rein, DAMTP Cambridge, 31. Aug.–2. Sep.; Daniel Bayliss, Mt. Stromlo Observatory, 31. Aug.–1. Sep.; Matthew Walker, Univ. Cambridge, 11.–18. Sep.; Keyhan Gultekin, Univ. Michigan, 12.–19. Sep.; Al Conrad, WM Keck Observatory, 16.–17. Sep.; Ian McGreer, Steward Observatory, 23.–25. Sep.; Edward Taylor, Univ. Sydney, 26.–29. Sep.; Frederic Vogt, 23. July–7. Oct.; Paul Molliere, Univ. Heidelberg, 2. Aug.–8. Oct.; Karina Voggel, Univ. Heidelberg, 1. Sep.–8. Oct.; Steven Beckwith, Univ. California, 28. Sep.–4. Oct.; Katharine Johnston, 28.–30. Sep.; Marco Baldi, Universe Cluster Munich, 28.–30. Sep.; Alex Wolszczan, Pennsylvania State Univ., 10. Sep.–15. Oct.; Witold Maciejewski, Liverpool Univ., 10.–17. Oct.; Simone Weinmann, MPA, 10.–15. Oct.; Wladimir Lyra, American Museum of Natural History, 17.–22. Oct.; Wesley Traub, JPL, 18.–22. Oct.; Nikoletta Sipos, Konkoly Observatory, 19.–22. Oct.; Genevieve Parmentier, Argelander Institut Bonn, 21. Oct.; Vasilii Gvaramadze, Sternberge Institut Moskau, 22. Oct.; Rumpa Choudhury, Bangalore Univ., 24.–27. Oct.; Matthias Knecht, 10. Aug.–31. Oct.; Joelle Walsh, UC Irvine, 31. Oct.–6. Nov.; Rachel Somerville, StSci, 1.–2. Nov.; Dmitry Wiebe, russian academy of sciences, 15. Oct.–14. Nov.; Vitaly Akimkin, russian academy of sciences, 15. Oct.–14. Nov.; Yancy Shirley, Steward Observatory, 1.–12. Nov.; Marc Schartmann, MPE, 9.–12. Nov.; Sebastiano Cantalupo, Cambridge Institute, 10.–12. Nov.; Thomas Ruppel, Univ. Stuttgart, 11. Nov.; Agnieszka Rys, IAC Teneriffe, 22. Oct.–21. Nov.; Cristina Ramos Almeida, Univ. Sheffield, 15.–19. Nov.; Angel Petrov, 15.–20. Nov.; Georgi Rumenov, 15.–20. Nov.; Carmelo Arcidiacono, INAF Bologna, 16.–18. Nov.; Teresa Villegas Aparicio, Instituto de Astrofísica de Andalucía, 1. Sep.–15. Nov.; Alex Lazarian, Univ. Wisconsin, 21.–23. Nov.; Morten Andersen, ESA/ESTEC, 22.–25. Nov.; Uwe Harlander, BTU Cottbus, 22.–24. Nov.; Morten Andersen, ESA/ESTEC, 22.–25. Nov.; Yaroslav Pavlyuchenkov, russian academy of sciences, 22.–29. Nov.; Conchi Cardenas, IAA, 23. Nov.–5. Dec.; Geraint Lewis, Univ. Sydney, 1.–3. Dec.; Andrew Gould, Ohio State Univ., 1.–5. Dec.; Nikolaos Fanidakis, Durham Univ., 1.–3. Dec.; Thomas Ruppel, Univ. Stuttgart, 2. Dec.; Senthamizh Pavai, NIT, Tiruchirappalli, 4. Oct.–10. Dec.; H. Kobayashi, Univ. Jena, 6.–10. Dec.; Jens Zuther, Univ. Köln, 6.–10. Dec.; Brandon Horn, American Museum of Natural History, 5.–12. Dec.; Koen Maaskant, Univ. Amsterdam, 7.–10. Dec.; Markus Janson, Univ. Toronto, 8.–11. Dec.; Jürgen Ott, NRAO, 12.–15. Dec.; Thibaut Prod'homme, Leiden Univ., 14.–15. Dec.; Zsolt Regaly, Konkoly Observatory, 31. Oct.–16. Dec.; Nikoletta Sipos, Konkoly Observatory, 28. Nov.–18. Dec.; Neal Turner, 6. Dec.–4. Mar. 2011; Sarah Rugheimer, Harvard Univ, 6.–21. Dec.; Peter Abraham, Konkoly Univ., 6.–16. Dec.; Thiem Hoang, Univ. Wisconsin, 15.–16. Dec.; Niall Deacon, IfA, 15.–17. Dec.; Thomas Robitaille, CfA, 15.–17. Dec.; Angela Adamo, Univ. Stockholm, 20. Dec.; Dominik Riechers, Caltech, 22.–24. Dec.

Due to our regular international meetings and workshops further guests visited the Institute, not listed here individually.

Calar Alto Observatory Almeria, Spain

Astronomy Coordination: Thiele (Deputy)
Telescope Technology and Data Processing: W. Müller

Departments

Department: Planet and Star Formation
Director: Thomas Henning

Infrared Space Astronomy: Oliver Krause, Zoltan Balog, Marc-André Besel, Thomas Blümchen, Jeroen Bouwman, Örs Hunor Detre, Ulrich Grözinger, Ralph Hofferbert, Rory Holmes, Ulrich Klaas, Hendrik Linz, Friedrich Müller, Markus Nielbock, Jan Pitann, Silvia Scheithauer, Anika Schmiedeke, Jürgen Schreiber, Amy Stutz

Star Formation: Henrik Beuther, Aurora Aguilar Sicilia, Tobias Albertsson, Miriam Benisty, Adrianus Bik, Paul Boley, Nicola Da Rio, Min Fang, Davide Fedele, Markus Feldt, Mario Gennaro, Dimtrios Gouliermis, Miwa Goto, Katherine Johnston, Jouni Kainulainen, Ralf Launhardt, Huabai Li, Rainer Lenzen, Nils Lippok, Diethard Peter, Sarah Ragan, Veronica Roccatagliata, Markus Schmalzl, Tim Schulze-Hartung, Dmitri Semenov, Bernhard Sturm, Roy van Boekel, Antonin Vasyunin, Tatiana Vasyunina, Wei Wang, Yuan Wang, Miaomiao Zhang, Svitlana Zhukovska

Brown Dwarfs / Exoplanets: Reinhard Mundt, Carolina Bergfors, Beth Biller, Mikaël Bonnefoy, Wolfgang Brandner, Joseph Carson, Guo Chen, Michaela Döllinger, Bertrand Goldmann, Felix Hormuth, Viki Joergens, Natalia Kudryavtseva, Maren Mohler, Boyke Rochau, Victoria Rodriguez Ledesma, Tim Schulze-Hartung, Johny Setiawan, Christian Thalmann, Patrick Weise, Matthias Zechmeister

Theory (SP): Hubertus Klahr, Hassnat Ahmad, Benoit Commerçon, Karsten Dittrich, Natalia Dzyçourkevitch, Mario Flock, Sebastian Kern, Rolf Kuiper, Christoph Mordasini, Christiaan Ormel, Ludovic Petitdemange, Nathalie Raettig, Ana Uribe

Laboratory Astrophysics: Friedrich Huisken, Yvain Carpentier, Cornelia Jäger, Sergey Krasnokutsky, Karsten Potrick, Gael Rouillé, Toulou Sabri, Torsten Schmidt, Mathias Steglich

Adaptive Optics: Wolfgang Brandner, Nicola Da Rio, Joseph Carson, Markus Feldt, Dimitrios Gouliermis, Stefan Hippler, Felix Hormuth, Natalia Kudryavtseva, Micaela Stumpf, Christian Thalm

Frontiers of Interferometry in Germany (FRINGE): Thomas Henning, Uwe Graser, Ralf Launhardt

Emmy-Noether-Group: Lisa Kaltenegger

MPG Junior Research Group: Cornelis Dullemond, Tilman Birnstiel, Mario Flock, Paola Pinilla, Zsolt Sandor, Fredrik Windmark, Andras Zsom

MPG Minerva Group: Cristina Afonso, Balasz Csak, Maximiliano Moyano, Nikolai Nikolov, Kai Uelzhoeffer

Department: Galaxies and Cosmology
Director: Hans-Walter Rix

Structure and Dynamics of Galaxies: Hans-Walter Rix, Crystal Brasseur, David Martinez-Delgado, Blair Conn, Sergey Koposov, Noelia Noel, Nicolas Martin, Anna Pasquali, Lan Zhang, Glenn van de Ven, Vesselina Kalinova, Ronald Laesker, Mariya Lyubenova, Sladjana Nikolic, Remco van den Bosch, Laura Watkins

Star Populations and Star Formation: Coryn Bailer-Jones, Rainer Klement, Chao Liu, Kester Smith, Paraskevi Tsalmantza, Fabian Walter, Roberto Decarli, Gisella de Rosa, Jacqueline Hodge, Eric Morganson, Karin Sandstrom, Andreas Schruba, Hsiang-Hsu Wang

Galaxy Evolution and Cosmology: Eric Bell, Anna Gallazzi, Christine Ruhland, Rosalind Skelton, Joe Hennawi, Neil Crighton, Gabriele Maier, Kate Rubin, Yujin Yang, Klaus Meisenheimer, Michael Fiedler, Mathias Jäger, Hélène Nicol,
Hans-Walter Rix, Kasper Borello Schmidt, Yu-Yen Chang, Balasubramanian Ramkumar, Arjen van der Wel, Stefano Zibetti

Aktive Galactic Nuclei: Klaus Meisenheimer, Leonard Burtscher, Christian Fendt, Christian Leipski,
Eva Schinnerer, Dario Colombo, Gaelle Dumas, Liu Fan, Brent Groves, Alexander Karim, Sharon Meidt, Mark Sargent, Tessel van der Laan,
Knud Jahnke, Katherine Inskip, Rene Andrae, Mauricio Cisternas, Dading Hadi Nugrohu,
Christian Fendt, Oliver Porth, Barghav Vaidya

Galaxy Formation: Andrea Macciò, Rahul Kannan, Benjamin Moster

Instrumentation: Thomas Herbst, Josef Fried, Jörg-Uwe Pott, Fulvio de Bonis, Roman Follert, Eva Meyer, Xianyu Zhang

Emmy-Noether-Groups: Eric Bell, Knud Jahnke

Teaching Activities

Winter Term 2009/2010

H. Beuter, Chr. Fendt: Introduction to Astronomy and Astrophysics I (Talk)
H. Beuther, Chr. Fendt, L. Burtscher: Introduction to Astronomy and Astrophysics I (Exercises)
Chr. Fendt, K. Meisenheimer: Workshop (IMPRS Seminar, with T. Lisker, ARI/ZAH
Th. Henning: Physics of Star Formation (Seminar)
S. Hippler: Experiment F36 "Wave Front Analysis" in Advanced Practical for Physicists (Practical)
F. Huisken: Clusters and Nanoparticles: Part I (Clusters) (Talk, FSU Jena)
H. Klahr, Chr. Mordasini: Numerical Practical (block course, with R. Banerjee, ITA/ZAH)
D. Lemke: Balloon-borne Astronomy (Lecture, University Stuttgart)
K. Meisenheimer: Colloquium at MPIA and LSW (with S. Wagner, LSW/ZAH)
K. Meisenheimer: Astrophysical sources of high energy radiation (Seminar, with S. Wagner, LSW/ZAH, J. Kirk, MPIK)
O. Porth: Introduction to Astronomy (Exercises)
B. Rochau: Physical Practicals IIA (Practicals)
H.-W. Rix: Observing the Big Bang (Talk)

Summer Term 2009

C. Dullemond: Computer Physics (Lecture)
C. Dullemond: Observational Astronomy (Lecture)
C. Dullemond: Astronomical-Astrophysical Practical (with A. Quirrenbach, LSW/ZAH)
Chr. Fendt, H. Beuther, C. Dullemond: Seminar on current research topics (IMPRS 1) (with A. Quirrenbach, LSW/ZAH)
Th. Henning: Advanced seminar on current research topics (IMPRS 2) (mit A. Just, ARI/ZAH)
S. Hippler: Experiment F36 "Wave Front Analysis" in Advanced Practical for Physicists (Practical)
F. Huisken: Cluster & Nanoteilchen II (Lecture, Universität Jena)
K. Jahnke: Introduction to Astronomy and Astrophysics II (Lecture)
H. Klahr: Introduction to Astronomy and Astrophysics III (Lecture, mit J. Heidt, LSW/ZAH, J. Krautter, LSW/ZAH, Th. Lisker, ARI / ZAH)
K. Meisenheimer, H.-W. Rix: Introduction to Astronomy and Astrophysics II (Exercises)
H. Mutschke, F. Huisken: Laboratory Astrophysics (Lecture, University Jena)
H.-W. Rix: Bahcall Talk (Lecture, Universität Tel Aviv, Israel)
R. van Boekel: Observational Astronomy (master course)

Winter Term 2010/2011

H. Beuther, Th. Henning: Star Formation (Lecture)
C. Dullemond: Mathematical Methods in Physics I – Teacher (Lecture)
Chr. Fendt: IMPRS seminar, Heidelberg University, (with C. Dullemond, Hennawi)
S. Hippler: Experiment F36 "Wave Front Analysis" in Advanced Practical for Physicists (Practical)
F. Huisken: Clusters and Nanoparticles I (Lecture, FSU Jena)
V. Joergens: Extrasolar Planets and Brown Dwarfs (Lecture)
H. Klahr, R. Mundt: Introduction to Astronomy and Astrophysics III (Lecture, with J. Heidt, J. Krauter)
H. Klahr, V. Joergens: Extrasolar Planets and Brown Dwarfs (Lecture)
A. Macciò: Advanced Numerical Techniques in Astrophysics (Lecture, Dark Cosmology centre, Kopenhagen, Niederlande)
R. Mundt, H. Klahr: Introduction to Astronomy and Astrophysics III (Seminar, with J. Krautter, LSW/ZAH, J. Heidt, LSW/ZAH)
H.-W. Rix: Galaxies (Lecture)
H.-W. Rix: Exercises on Galaxies (Exercises)
J. Setiawan: Extrasolar Planets (Lecture at the Bandung Institute of Technology, Bandung, Indonesia)

Service in Committees

Coryn Bailer-Jones: Member of the PAC-Committee at MPIA; Manager of the Subconsortium "Astrophysical Parameters" in the GAIA Data Processing and Analysis Consortium; Member of the GAIA Data Processing and Analysis Consortium Executive
Zoltan Balog: Member of the NASA ADAP review panel
Henrik Beuther: Referee of the IRAM Program Committee; Deputy of the German SOFIA Science Working Group (GSSWG); Board member of the scientific Ernst-Patzer-Foundation; Member of the LINC-NIRVANA Science Team
Arjan Bik: Panel-Member of the HST TAC
Leonard Burtscher: Member of the PhDnet-Working Group "Surveys"
Cornelis Dullemond: Member of the PAC-Committee at MPIA
Christian Fendt: Invited external Expert of the Visiting Committee for the Laboratoire d'astrophysique de l'observatoire de Grenoble, AERES, France; Member of the DAAD Referees Committee "International promovieren in Deutschland (IPID)"
Wolfgang Gässler: Member of the IAU Working Group on Optical Interferometry Data Standards
Bertrand Goldman: Member of the PANIC Science Team, Member of the Science Policy Oversight Committee of the PanSTARRS1 Consortium
Dimitrios A. Gouliermis: Member of the Time Allocating Committee of the Calar-Alto-Telescopes
Roland Gredel: Chair of the OPTICON Board, Member of the OPTICON Executive Committee, Member of the

Telescope Directors Forum, Member of the ELT Science and Engineering Committee, Chair of the LBT Internal Operational Readiness Review, Chair of the LBT Time Domain Observations, Chair of MPIA STAC; Support in the board of the LBT-Beteiligungsgesellschaft

Joseph Hennawi: Member of the ESO OPC Time Allocation Committee

Thomas Henning: Vice president of the ESO Council; Member of the Scientific Advisory Committee; Member of the Thüringer Landessternwarte, Tautenburg; Member of the Selection Committee at the Dutch Academy Professorship Programme; Chair of the ERC Panel for Advanced Grants "Universe Science"; Chair of the LBT-Beteiligungsgesellschaft; Member of the CAHA Executive Boards; Member of the JWST MIRI Science Teams; Chairman for Astronomy of the Leopoldina; Coeditor of "Sterne und Weltraum"

Tom Herbst: Member of the LBT Science and Technical Committee; Member of the ESO Science and Technical Committee; Chair of the European ELT Science and Engineering Committee

Klaus Jäger: Board member of the Astronomischen Gesellschaft (Press Officer); Member of the Scientific Board of International Summer Science School Heidelberg (ISH), Support in the Board of the LBT-Beteiligungsgesellschaft and of the Rat Deutscher Sternwarten

Knud Jahnke: Member of the HST TAC; Member of the ESO TAC

Lisa Kaltenegger: Board member der NASA Extrasolar Planet Analysis Group

Ulrich Klaas: Member of the HERSCHEL Calibration Steering Group; Member of the HERSCHEL Schedule Planning Group; Chair of the library committee at the MPIA

Hubert Klahr: Panel-Member of the NASA Origins

Martin Kürster: Member of the ESO Observing Programmes Committee; Chair of the ESO OPC Panel C3; Referee of the OPTICON (EC EP7) trans-national Access programm and at A & A

Ralf Launhardt: Member of the Strategic Time Allocation Committee at the MPIA; Scientific Chair of the project "Exoplanet Search with PRIMA"

Christoph Leinert: Member of the ESO OPC panels; Member of the Hungary Academy of Sciences; Member of the External Counselling Body for the Konkoly Observatory

Nicolas Martin: Member of the Pan-STARRS 1 science consortium Science Council; Co-Chair of the Pan-STARRS Key-Project 5

Reinhard Mundt has been Ombudsman of MPIA

Markus Nielbock: Member of the HERSCHEL PACS Instrument Control Centre (ICC)

Hans-Walter Rix: Member of the scientific board of the Astrophysikalischen Instituts Potsdam; Chair of the PS1 Science Consortium; Member of the NIRSPEC Science Team; Member of the BMBF Referees Committee "Astrophysics and Astroparticle Physics"; Member of the DFG Fachkollegien; Board member of the Astronet Infrastructure Roadmap Working Group

Eva Schinnerer: Member at the ESO OPC panel; Referee for NRAO VLA / VLBA proposal; Member of the PhD Advisory Committee at MPIA; Project scientist for bei LINC-NIRVANA; Member of the "Viva voce" of the PhD-Students

Glenn van de Ven: Member of the Selection Committee for the scientific Ernst-Patzer Prize; Member of the LINC-NIRVANA Science Team

Fabian Walter: Member of the NRAO PASEO

Further Activities

Responsible for the Girls' Day on 22 April at the MPIA were Vianak Naranjo, Natalie Raettig, and Silvia Scheithauer.

The 8-part lecture series "Astronomy on Sunday morning" in June and August was organized by Klaus Jäger, Markus Pössel, and Axel M. Quetz.

Cornelis Dullemond organized the "Mini-Research for Undergraduate students".

On March 24 and 25, we had an evaluation of the Institute by the Scientific Advisory Board (Fachbeirat).

The meeting of the Board of Trustees was held on Oct. 14.

On Nov. 12th was an information day of the Haus der Astronomie (HdA) for the employees of the HdA partner organizations.

The topping out ceremony for the HdA on the grounds of the MPIA was on December 17.

The BOGy-program for students between Aug. 30 and Sept. 3rd was organized with the support of Klaus Meisenheimer, Eva Meyer, Markus Pössel, Leonard Burtscher, Benjamin Moster, Silvia Scheithauer, Marc-André Besel and Christiane Hölscher.

During the year, a total of 650 visitors in 27 groups were guided through the Institute (Axel M. Quetz, Natalie Raettig, Kelly Foyle, Christine Ruhland and others).

There were 13 Press Releases published and numerous Radio and Television interviews given (Klaus Jäger, Markus Pössel, Axel M. Quetz and others).

Isabel Cristina Afonso held the office of Equal Opportunity at MPIA and was representative of the Equality Officer in the CPT section of the MPG. Vianak Naranjo was their representative at MPIA and took over the Office of Equal Opportunity at MPIA in October.

Leonard Burtscher published the largest MPG-wide survey among PhD-students by means of a joint press release with the MPG President on November 18.

Klaus Jäger designed and produced a video / Audio Trailer for the Planetarium Mannheim, and a Webcast prototype for the Spectrum Verlag Heidelberg. He wrote press releases for the MPIA, the Astronomische Gesellschaft

(AG), the Rat Deutscher Sternwarten (RdS) and the LBT-Beteiligungsgesellschaft (LBT-B) and organized the Visitor Colloquium at MPIA (with Gallazi, Meidt, Klahr). He is Press Officer and Board member of the AG and an active member of the Förderkreis Planetarium Göttingen and the Freundeskreis Planetarium Mannheim.

Mark Nielbock participated in the "Day of Astronomy" 2010 on 24 April. He drew up the design of the HERSCHEL-Theme-Area with infrared experiments for the Engadiner Astronomiefreunde at the local primary school in St. Moritz, Switzerland. He participates also in the Astronomieschule e.V.

Axel M. Quetz participated in the drafting and design of the 49th Year of the magazine "Sterne und Weltraum".

Jacob Staude participated in the Publication of the 49th Year of the magazine "Sterne und Weltraum".

Natalie Raettig participated in the organization of the Students' Workshop, 7-14. May

Christine Ruhland and Markus Schmalzl handed over their position as student representatives of MPIA to Tessel van der Laan and Karsten Dittrich in November.

Christian Thalmann designed a tutorial on "Angular differential imaging using the LOCI pipeline" in December.

Compatibility of Science, Work, and Family

In recent years, the issue of compatibility of science, work, and family at the MPIA was integrated as a future-oriented concept within the staff recruitment processes. Thus, the Institute offers beside excellent research conditions also an optimal environment for the scientific work and therefore promotes the competitiveness in international comparison.

The practical solutions of MPIA to support the compatibility of science, work, and family have been expanded and strengthened. Additional to the previously existing 20, further allocation rights in daycare centers could be acquired. The child care directly at the Institute is guaranteed by means of a special room for child care and the Baby-office. Together with the MPI for Nuclear Research (also in Heidelberg), MPIA focused during the past months on finding a solution for a future daycare center close to the institute.

Moreover, also the issue of compatibility of work and the care of familiy relatives plays a role. The flexibility of working hours and working place during special family related circumstances will be supported. The cooperation within the dual-career network of the scientific institutes in Heidelberg was deepened and expanded. In particular a scientific career with its changes in position and typical visits to foreign countries is often a challenge for partners and the whole family. The International Office and the administration support employees and guests regarding all aspects of work and family, housing and dual career. In the network with other scientific institutions a common Job Board was launched in order to specifically support the finding of a job in Heidelberg. The Internet-based job board lists all internal and public job offers of the research institutions belonging to the network at the following web site: www.familie-heidelberg.de/bffh/dual_career

It is still the goal of MPIA to deepen and expand the already existing structures for the support of work and family.

Awards

Joseph Hennawi received the Sofja Kovalevskaja Awards of the Federal Ministry for Education and Research (BMBF), conferred by the Alexander von Humboldt Foundation Joe Hennawi's prize money comes to 1.45 million Euro. The award was conferred by Annette Schavan, Federal Minister for Education and Research, and Helmut Schwarz, President of the Humboldt Society, at a ceremony in Berlin on 9 November.

For his pioneering research on dark matter halos of galaxies, Surhud More received the Otto Hahn Medal of the Max-Planck-Society for outstanding achievements of young scientists.

The this years Ernst Patzer Prize winners were:

Sarah Martell, for her paper "Light-element abundance variations in the Milky Way halo (2010, Astronomy & Astrophysics 519, A14),

Jouni Kainulainen, for his publication "Probing the evolution of molecular cloud structure: From quiescence to birth" (2009, Astronomy & Astrophysics 508, L35), and,

Andras Zsom for his paper "The outcome of protoplanetary dust growth: pebbles, boulders, or planetesimals? II. Introducing the bouncing barrier (2010, Astronomy & Astrophysics 513, A57).

Marc-Andre Besel won the Max Planck Research Group Award of the Max Planck Society and David Martinez Delgado received the Humboldt Fellowship for Advanced Research.

Christiaan Ormel received the "Van Swinderenprijs" of the Royal Natuurkundig Genootschap Groningen (KNG) of the Dutch Physical Society for the best doctoral thesis of the year 2008.

Hans-Walter Rix was entrusted with the Emilio Segre Lectureship and the John Bahcall Lectureship.

Cooperation with Industrial Companies

Aachener Quarz-Glas, Aachen
Adolf Pfeiffer GmbH, Mannheim
Agilent Technologie, Böblingen
Air Liquide GmbH, Pfungstadt
ALPHA Übersetzungen, Heidelberg
Alternate Computer Versand, Linden
AMERICA II EUROPE GmbH, Mönchengladbach
ANDUS ELECTRONIC GMBH, Berlin
Aqua Technik Gudat, Neulußheim
Arrow Central Europe GmbH, Dreieich
ASB Management-Zentrum-Heidelb, Heidelberg
asknet AG, Karlsruhe
Astrium GmbH, Friedrichshafen
Astrophysical Research Consort, Seattle, Washington
ASYS, Dornstadt
ATP Messtechnik GmbH, Ettenheim
Aufzug-Service M. Gramlich GmbH, Ketsch
Austerlitz Electronic GmbH, Nürnberg
AVIS, Oberursel
AVNET EMG GmbH, Poing
B.E.S.T., Forst
B+S Express Transport GmbH, Weinheim
Baader Planetarium GmbH, Mammendorf
Baier Digitaldruck, Heidelberg
Baker & Harrison, München
BANDELIN electronic GmbH, Berlin
BÄR GmbH, Frankfurt
Bechtle ÖA Direkt, Neckarsulm
Bernhardt Nutzfahrzeuge GmbH, Heidelberg
Billettfabrikation+Druckerei, KETSCH
Binder Elektronik GmbH, Sinsheim
Blitz Button+Wagner Werbung Gm, Dielheim
Börsig GmbH, Neckarsulm
Brall Software GmbH, Sontra
Bürklin OHG, München
Bürma Büromarkt, Stuttgart
Büro-Mix GmbH, Mannheim
Büro-Taxi GmbH, Kamp-Lintfort
Buster Altöl GmbH, Mannheim
CADFEM GmbH, Grafing
Cadmus Journal Services, Charlotte
Cambridge University Press, Cambridge
CAMCenter GmbH, Nidderau
Camfil KG, Reinfeld
Carl Zeiss Optronics GmbH, Oberkochen
Circular GmbH, Stuttgart
Coda KG, Waldkirch
Colordruck, Leimen
Comarch Software und Beratung, München
Computacenter AG & Co oHG, Stuttgart
COMTRONIC GmbH, Wilhelmsfeld
Conrad Electronic GmbH, Hirschau
Contag GmbH, Berlin
Container Weis, Leimen
CreaSo GmbH, Gilching
Crowne Plaza Heidelberg, Heidelberg
Cryophysics GmbH, Darmstadt
CTS GmbH, Hechingen
CWS-boco Deutschland, Dreieich
D+C-Airparts Battery, Mörfelden-Walldorf
DAAD, Bonn
Data Translation GmbH, Bietigheim-Bissingen
db electronic Daniel Böck GmbH, Ehringshausen
DELL-Computer GmbH, Frankfurt
DELTA-V GmbH, Wuppertal
Deti GmbH, Meckesheim
DFN-Verein, Berlin
DHL Express Germany GmbH, Köln
Dicronite U.T.E. Pohl GmbH, Iserlohn
Dietmar Dreier, Duisburg
Digi-Key, Enschede
Distrelec Schuricht GmbH, Bremen
DPS Vakuum, Großrinderfeld
DPV Elektronik Service GmbH, Eppingen
Drucker Druck, Bietigheim
Dürkes & Obermayer GmbH, Edingen-Neckarhausen
E. Strauss GmbH & Co., Biebergemünd
EBJ, Ladenburg
EDICO-Equipment GmbH, Nürnberg
Edmund Optics GmbH, Karlsruhe
EDP Sciences, Les Ulis Cedex A France
Elektro-Steidl, Weinheim
Elna Transformatoren GmbH, Sandhausen
Elsevier Publisher, Amsterdam
EMS-Elektro Metall Schwanenmüh, Schwanenmühle
ERNI Electronics GmbH, Adelberg
ESO – European Southern, Garching
Essenpreis Haustechnik GmbH, Östringen
Europcar Inter Rent, Hamburg
EUROstor GmbH, Filderstadt
Excel Technology Europe GmbH, Darmstadt
Faber Industrietechnik GmbH, Mannheim
Farben Specht, Bammental
Farnell GmbH, Oberhaching
Faulhaber GmbH & Co KG, Schönaich
Federal Express Europe Inc., Kelsterbach
Fels Fritz GmbH Fachspedition, Heidelberg
Fertigungsmaschinenbau Kilgens, Wiesen
Fischer Elektronik GmbH & Co., Lüdenscheid
Fisher Scientific GmbH, Schwerte
FlowCAD EDA-Software Vertrieb, Feldkirchen
FPS-Werkzeugmaschinen GmbH, Warngau
Freiesleben Fliesen GmbH, Waghäusel
Friedrich Wolf GmbH, Heidelberg
Fritz Zugck, Leimen
Gabler Werbeagentur GmbH, München
Gaerner GmbH, Frankfurt
Ganter GmbH, Walldorf
Garlock GmbH, Neuss
Gastro master Aldinger GmbH+Co, Pforzheim
Gebr. Reinfurt GmbH & Co. KG, Rimpar
Geier Metall-u.Stahlhandel Gmb, Mannheim
GePaNet, Wasserburg
Getränkemärkte Sprengel, Gaiberg
Glas-Reidel, Heidelberg
Gleich Service-Center GmbH, Kaltenkirchen
Glenair Electronic GmbH, Steinbach
Goodfellow, Bad Nauheim
Gößl+Pfaff GmbH, Karlskron
GRAVIS Computervertr. GmbH, Berlin

Grulms Pneumatik GmbH, Grünstadt
GSF – Auswertungsstelle im Hel, München
Gummispezialhaus Körner, Eppelheim
Gutekunst & Co. Federnfabrik, METZINGEN
Guttroff Friedrich GmbH, Wertheim
Hach GmbH, Pfungstadt
Hagemeyer Deutschland GmbH &Co, Heidelberg
Hahn u. Kolb GmbH, Stuttgart
Haufe,Rudolf-Verlag GmbH & Co, Freiburg i. Br.
Haus der Technik e.V., Essen
HDI Gerling, München
Heise Zeitschriften Verlag, Stuttgart
HELBIG Medizintechnik, Neuenstadt
Hera Laborsysteme GmbH, Blaufelden
Herose GmbH, Bad Oldesloe
Heuser Friedrich GmbH, Heidelberg
Hewlett Packard GMBH, Böblingen
Hilti Deutschland GmbH, Heidelberg
HM Industrieservice GmbH, Kronau
Hoffmann Nürnberg GmbH, Nürnberg
HSD Consult GmbH, München
Huber + Suhner GmbH, Taufkirchen
Hummer + Rieß GmbH, Nürnberg
HWP Architekturbüro, Heidelberg
HY-LINE Power Components Vertr, Unterhaching
IBF-Automatisierungs- und Sich, Vils
IBV - Ingenieurbüro, Heidelberg
Industriebedarf Oberhausen GmbH, Ketsch
infopaq Deutschland GmbH, Kornwestheim
Ingenieurbüro Schlossmacher, Unterschleissheim
INNEO Solutions GmbH, Ellwangen
INOTEC electronics GmbH, Lauffen a.N.
IOP Publishing Ltd., Bristol
ISOLOC Schwingungstechnik GmbH, Stuttgart
item Industrietechnik, Ulm
Jacobi Eloxal GmbH, Altlussheim
Janos Technology Inc., Keene
Jehier S.A., Chemille
John Wiley & Sons Limited, Chichester
joke Technology GmbH, Bergisch Gladbach
Jungheinrich Vertrieb Deutschl, Hamburg
KA-WE GmbH, Schwetzingen
Kai Ortlieb Buchbinderei, Eppelheim
KAISER + KRAFT, Stuttgart
Katzer Printvision Gmbh, Sandhausen
Keil-ARM Germany GmbH, Grasbrunn
Keithley Instruments GmbH, Germering
Kniel GmbH, Karlsruhe
KOCO MOTION GmbH, Dauchingen
Kohlhammer W. Druckerei, Stuttgart
Konecranes GmbH, Viernheim
Konica Minolta Businesss, Mannheim
Körber TH. GmbH, Sensbachtal/Odw.
Kroschke GmbH, Braunschweig
Kruse Sicherheitssysteme GmbH, Stelle
Kugler GmbH, Salem
Kühne & Nagel (AG&Co.)KG, Bremen
L.+H. Hochstein GmbH + Co., Heidelberg
Lapp Kabel GmbH, Stuttgart
Layertec GmbH, Mellingen
LeCroy Europe GmbH, Heidelberg
Lemo Elektronik GmbH, München
Linde AG, Mainz-Kostheim
Linguatec Sprachtechnologien G, München
Lista GmbH, Bergneustadt
LWS-Technik GmbH & Co., Heilbronn
Maas International GmbH, Bruchsal
Mack GmbH, Heidelberg
Mädler GmbH, Stuttgart
MAXIM GmbH, Planegg
MEGATRON Elektronik-ELPAC, Putzbrunn
Meilhaus Electronic GmbH, Puchheim
Melitta Systemservice GmbH & Co. KG, Minden-Dützen
Melles Griot, Bensheim
Metallbau GLAWION GmbH, Eberswalde
MICOS, Eschbach
Micro Warehouse, Mainz-Kastel
Microstaxx GmbH, München
Mikrotron GmbH, Unterschleißheim
MOBOTIX AG, Langmeil
Möller-Wedel Optical GmbH, Wedel b. Hamburg
MTS Systemtechnik GmbH, Mertingen
Multi PCB Ltd. (GmbH), Hofolding-Brunnthal
Mura, Metallbau, Viernheim
MVC Mobile Video Com., Frankfurt
National Instruments, München
Neolab Laborbedarf, Heidelberg
Neopost GmbH & Co. KG, München
Netzsch-Gerätebau GmbH, Selb
Neue Mediengesellschaft Ulm mbH, München
Neumann Rupert Druckerei, Heidelberg
Newport Spectra-Physics GmbH, Darmstadt
Nibler W. GmbH, Walldorf
Nies Elektronic GmbH, Frankfurt
NOVOTEK GmbH
Ocean Optics Germany GmbH, Ostfildern
Omnilab GmbH, Berlin
Omnitronik Vertriebs- GmbH & Co. KG, Heidelberg
Optima Research Ltd., Stansted
ORBITEAM SW-GmbH, Bonn
Otto Office GmbH & Co. KG, Hamburg
OWIS GmbH, Staufen
Oxford Instruments GmbH, Wiesbaden
Pfeiffer & May, Heidelberg
PFEIFFER VACUUM GmbH, Asslar
Pfister BÜRO, Leimen/St.Ilgen
Philipp Lahres GmbH, Weinheim
Physik Instrumente (PI), Karlsruhe
Phytec Messtechnik, Mainz
Phytron-Elektronik GmbH, Gröbenzell
Phywe Systeme GmbH & CO.KG, Göttingen
Piezosystem Jena GmbH, Jena
POG – Präzisionsoptik Gera Gmb, Gera
Pollin Electronic GmbH, Pförring
Pro-Com Datensysteme GmbH, Eislingen
R.A. Zimmermann KG, Dietzenbach
R.E.D., Rodgau - Jügesheim
Rahm GmbH & Co.KG, Heidelberg
ratioform, Ladenburg
REEG GmbH, Wiesloch
Reha-Klinik, Heidelberg
Reichelt Elektronik, Sande
Rhein-Neckar-Zeitung, Heidelberg
Riekert & Sprenger, Wertheim
Rittal GmbH + Co.KG, Herborn
RMG Metallfachhandel GmbH, Ladenburg
Röhr + Stolberg GmbH, Krefeld
Rolf Dernehl, Mannheim
Roth Carl GmbH & Co.KG, Karlsruhe
RS Components GmbH, Mörfelden-Walldorf

Rufflar, Laudenbach
S & F Tours, Ladenburg
SAMTEC Germany, Germering
Sanitär-Raess GmbH, Heidelberg
Scantec GMBH, München
Schäfer Fritz GmbH, Neunkirchen
Schäfer-Shop GmbH, Betzdorf
Schaffland Detlef, Handelsvertretung, Leverkusen
Schenker Deutschland AG, Mannheim-Rheinau
Schlapp-Möbel GmbH, Neu-Ansbach
Schneider Günther GmbH, Sandhausen
Schrauben-Jäger AG, Viernheim
Schroff GmbH, Straubenhardt
Schulz H.u.G. Ingenieure, Heidelberg
SCHUPA Schumacher GmbH, Walldorf
Schuricht GmbH + Co KG, Bremen
Scientific Instruments GmbH, Gilching
SE Spezial-Electronic AG, Bückeburg
Sicon Socomec GmbH, Mannheim
Siemens Enterprise, Mannheim
Sky Blue Microsystems GmbH, München
SLCR Lasertechnik GmbH, Düren
SMS System-Managment, Aachen
Spektrum der Wissenschaft, Heidelberg
Stadtwerke Heidelberg AG, Heidelberg
Stäubli Tec Systems GmbH, Bayreuth
Stempel Bauer, St. Leon-Rot
Stollfuß Verlag, Bonn
Tchibo GmbH, Hamburg
Technik Direkt, Würzburg
Telemeter Electronic GmbH, Donauwörth
TETRONIK GmbH, Tanusstein-Wehen
tfi Ingenieure Elektrotechnik, Mannheim
The MathWorks GmbH, Ismaning
Theile Büro-Systeme, Speyer
Thermodyne GmbH, Osnabrück
Thorlabs GmbH, Dachau
TLS Personenförderung GmbH, Heidelberg
Topcart International GmbH, Erzhausen
TOWER ELECTRONIC COMPONENTS GmbH, Dossenheim
tproneth GmbH & Co. KG, Puchheim
transtec AG, Tübingen
Trinos Vakuum-Systeme GmbH, Göttingen
TÜV Life Service GmbH, München
TÜV Süd Industrie Service GmbH, Mannheim
TWM Ottenstein GmbH, Mannheim
United Parcel Service, Neuss
Varian Vacuum Technologies, Leini Torino
Verlag Reckinger & Co. KG, Siegburg
Vigot GmbH, Bremen
Volker Röhrs, Stelle
VZG Verbundzentrale des GBV, Göttingen
Walter Bautz GmbH, Griesheim
Wamser Büro Service, Mannheim
Watlow GmbH, Kronau
WEKA MEDIA GmbH&Co. KG, Kissing
Wero-medical, Sandhausen
Wiesemann u. Theis GmbH, Wuppertal
Winter Maschinen und Werkzeuge, Idar-Oberstein
Witzenmann Rhein-Ruhr GmbH, Xanten
Wolters Kluwer Deutschland, Neuwied
Würth Elektronik GmbH & CO.KG, Künzelsau
Yamaichi Electronics, München

Conferences, Scientific, and Popular Talks

Conferences Organized

Conferences Organized at the institute:

KINGFISH Team Meeting, MPIA, 18.–19. Feb. (E. Schinnerer, Sh. Meidt, H.-W. Rix)

Infrared Emission, ISM and Star Formation, MPIA, 22.–24. Feb. (G. Dumas, E. Schinnerer, M. Sargent, A. Karim, S. Koltes-Al-Zoubi, H. Seifert)

Meeting of the MPIA-Fachbeirat, MPIA, 23.-25. March (K. Jäger, Th. Henning, H.-W. Rix, H. Witte-Nguy)

LINC-NIRVANA Internal Review Meetings, MPIA, 27. Apr., 15. July, 15. Nov., 16. Dec. (M. Kürster)

CAHA-TAC-Meeting, MPIA, 29.–30. Apr. (K. Jäger, D. J. Bomans (Bochum))

HERSCHEL Calibration Steering Group Meeting #25, MPIA, 10. May (U. Klaas, M. Nielbock)

THESIS Workshop, MPIA, 2. Aug. (Th. Henning)

LINC-NIRVANA Consortium Meeting, MPIA, 4.–6. Oct. (M. Kürster)

LINC-NIRVANA Science Team Meeting, MPIA, 5. Oct. (E. Schinnerer)

Sitzung des MPIA-Kuratoriums, MPIA, 14. Oct. (K. Jäger, Th. Henning, H.-W. Rix, M. Janssen-Bennynck)

Other Conferences Organized:

MIRI Science Team & Co-PI/NPM Meetings, Madrid, 13.–14. Jan. (Th. Henning)

MPIA-External Retreat, Obrigheim, 25.–26. Jan. (K. Jäger, Th. Henning, H.-W. Rix)

LINC-NIRVANA Consortium Meeting, Univ. Cologne, 2.–3. March (M. Kürster)

ARGOS Final Design Review, Tuscon, 27.–28. March (W. Gässler)

MPIA Galaxy & Cosmology group retreat, Maulbronn, 21.–23. Apr. (H.-W. Rix, N. Martin, T. van der Laan, M. Sargent)

7. MPIA Student Workshop, Norddeich, Nordsee, 7.–14. May (M. Stumpf, A. Schmiedeke, B. Sturm)

"Science with ALMA Band 5", INAF, Rom, 24.–25. May (F. Walter)

PAH Symposium, Toulouse, 31. May–4. June (Th. Henning)

Early Phases of Star Formation, EPOS 2010, Ringberg Castle, 14.–18. June (Th. Henning, J. Steinacker, H. Beuther, M. Nielbock, H. Linz)

"Modern Technologies in Space- and Ground-based Telescopes and Instrumentation", SPIE, San Diego, USA, 27. June–2. July (D. Lemke)

KINGFISH Team Meeting, Ringberg Castle, 11.–17. July (E. Schinnerer, S. Meidt, K. Sandstrom, Rix)

"Molecules in Galaxies", Oxford, 26.–30. July (F. Walter)

IMPRS Summer School: "First Stars and Cosmic Reionization", Heidelberg, 6.–10. Sep. (H.-W. Rix, Chr. Fendt, M. Bartelmann, R. Klessen)

Meeting "Public Outreach in der Astronomie" at the Annual Meeting of the Astronomische Gesellschaft, Bonn, 17. Sep. (K. Jäger, M. Pössel)

JWST/MIRI Science Meeting, Ringberg Castle, 20.–23. Oct. (O. Krause)

PSF Group retreat 2010, Löwenstein/Hößlinsülz, 27.–29. Oct. (R. van Boekel, J. Kainulainen, H. Linz, A. Stutz)

"Adaptive Optics, Large Telescopes, and Solar Energy", Kloster Seeon, 31. Oct.–3. Nov. (T. Herbst)

Planetary Population Synthesis: The Predictive Power of Planet Formation Theory, 29. Nov.–3. Dec., Ringberg Castle (Th. Henning, H. Klahr, Chr. Mordasini)

HERSCHEL Calibration Workshop, ESAC, Villafranca, Spain, 13.–15. Dec. (U. Klaas)

Conferences and Meetings Attended, Scientific Talks and Poster Contributions

Cristina Afonso: PLATO Space Mission Meeting, Aahrus, Denmark

Rene Andrae: "Evolution of galaxies, their central black holes and their large-scale environment", Potsdam, 20.–24.9. (Poster)

Coryn Bailer-Jones: "Future Professional Communication in Astronomy II", CfA Harvard, 13.–14. Apr.; AG, Bonn, 14.9. (Talk); ADASS 20, Boston, USA, 8.–11. Nov. (Talk)

Zoltan Balog: HERSCHEL Calibration Workshop, EsaC, Villafranca, Spain, 13.–15. Dec.; HERSCHEL/PACS ICC meeting, Konkoly Observatory, Budapest, Hungary, 5.–7. Oct.; HERSCHEL/PACS Photometer meeting, CEA Saclay, France, 15.–17. Sep.; HERSCHEL and the formation of stars and planetary systems, Saro, Sweden, 6.–9. (Poster); HERSCHEL/PACS documentation workshop, MPE Garching, 9.–11. June; HERSCHEL First Results Symposium, ESTEC Noordwijk. The Netherlands, 4.–7. May; HERSCHEL/PACS ICC meeting, MPE, Garching, 12.–14. Apr.; HERSCHEL/PACS ICC meeting and RP readiness review, MPE Garching, 17.–19. Feb..; HERSCHEL/SPIRE-PACS Map making review, Cardiff, UK, 8.–9. Feb.

Carolina Bergfors: IAU Symposium 276, "The Astrophysics of Planetary Systems: Formation, Structure, and Dynamical Evolution", Turino, Italy, 11.–15. Oct. (Poster)

Marc-André Besel: "Stormy Cosmos – The Evolving ISM from SPITZER to HERSCHEL and Beyond", Pasadena, CA, USA, 1.–4. Nov. (Talk)

Henrik Beuther: "Great Barriers in High-Mass Star Formation", Townsville, Australia, 13.–17. Sep. (Talk)

Arjan Bik: "From Stars to Galaxies – Connecting our understanding of star and galaxy formation", Gainesville, Florida, 6.–10. Apr. (Talk); EPOS 2010, Ringberg Castle, 14.–18. June (Poster)

Tilman Birnstiel: "Planetary Population Synthesis", Ringberg Castle, 29. Nov.–3. Dec. (Talk)

Steve Boudreault: "Cool Stars 16", Seattle, WA, USA, 29. Aug.–2. Sep.

Crystal Brasseur: “A universe of dwarf galaxies”, Lyon, France, 14. June (Poster); PAndAS – Pan-Andromeda archaeological Survey Meeting, Cambridge, UK, May

Leonard Burtscher: AGN-Workshop, MPE, Garching, June 2010 (Talk); JENAM 2010, Special Session “Science cases for optical and infrared interferometry”, Lissabon, Portugal, 6.–10. Oct. (Talk)

Mauricio Cisternas: “Evolution of galaxies, their central black holes and their large-scale environment”, Potsdam, 20.–24. Sep. (Poster); “What drives the growth of black holes?”, Durham, UK, 26.–29. July (Poster); 2010 COSMOS Team Meeting, Honolulu, HI, USA, 7.–10. June (Talk)

Benoit Commerçon: “The origin of stellar masses”, Constellation european Marie Curie network, Teneriffe, Spain, 18.–22. Oct. (Talk); “Frontiers in Computational Astrophysics”, Lyon (France), 11.–15. Oct. (Talk); EPoS 2010, Ringberg Castle, 14.–18. June (Poster); “Computational star formation”, IAU 270 Symposium, Barcelona (Spain), 31. May–4. June (Talk); “Magnetic fields: from Core Collapse to Young Stellar Objects”, UWO London, Canada, 17.–19. May (Talk)

Roberto Decarli: “54° congresso SAIt”, Napoli (Italy), 4.–7. May (Talk); “AGN9: Black holes and revelations”, Ferrara (Italy), 24.–27. May (Talk); “What drives the growth of black holes?”, Durham (UK), 26.–29. July (Talk); “PS1 Science consortium meeting 2010”, Belfast (UK), 30. Aug–3 Sep.; “Astronomische Gesellschaft Annual meeting”, Bonn, 13.–17. Sep. (Talk)

David Martinez Delgado: “Stellar population in the cosmological context”, Space Telescope Science Institute, Baltimore, USA, 3.–6. May; “Big Science with Small Telescopes, The role of 2–4 m Telescopes in the Era of the Large and Extremely LargeTelescopes”, Schloss Dornburg, 19.–22. Oct. (Talk); PS1 Science Consortium meeting 2010, Queen’s University, Belfast, Northern Ireland, 30. Aug.–3. Sep.

Karsten Dittrich: Joint meeting: “Paneth Colloquium” & “The first 10 million years of the solar system”, 27.–30. Oct. (Poster)

Cornelis Dullemond: AG General Assembly, Bonn, 14.–17. Sep.; ESO Workshop on HERSCHEL/ALMA, Garching, 17.–19. Nov. (Talk)

Gael Dumas: “Infrared Emission, ISM and Star Formation”, MPIA, 21.–24. Feb. (Talk); “Central Massive Objects: The Stellar Nuclei-Black Hole Connection”, ESO, Garching, 22.–25. June (Talk); “Puzzles of galactic nuclei”, MPE (Garching), 28.–30. June (Talk); “Molecules in Galaxies”, Oxford, UK, 26.–30. July (Talk); Astronomische Gesellschaft Annual Meeting and General Assembly, Bonn, 13.–17. Sep. (Talk); “Observing with ALMA – Early Science”, IRAM Grenoble (France) 29. Nov.–1. Dec.

Min Fang: The second Chinese-German Workshop on Star and Planet Formation, Kiel, 27.–30. July

Roman Follert: SPIE Astronomical Telescopes and Instrumentation, San Diego, CA, USA, 27. June–2. July (Poster)

Wolfgang Gässler: ARGOS consortium meeting, Bonn, 2.–3. Feb. (Talk); ARGOS Final Design Review, Tuscon, 27.–28. March (Talk); OPTICON JRA1 General meeting, Freiburg, 7.–8. Oct. (Talk); ARGOS consortium meeting, Garching, 4.–5. Nov. (Talk)

Anna Gallazzi: Calar Alto Legacy Integral Field Area (CALIFA) collaboration kick-off meeting, Almeria, Spain, 7.–8. June (Talk)

Mario Gennaro: “The Origin and Fate of the Sun: Evolution of Solar-mass Stars Observed with High Angular Resolution”, Garching, 2.–5. March (Poster); “The Origin of Stellar Masses”, Teneriffe, Canarian Islands, Spain, 18.–22. Oct. (Poster)

Dimitrios A. Gouliermis: Annual Meeting of the Astronomische Gesellschaft, Bonn, 13.–17. Sep. (Talk); “Science with the Hubble Space Telescope – III two decades and counting”, Venice, Italy, 11.–14. Oct. (Poster)

Roland Gredel: ESE ELT meeting, Garching, 19. Apr.; OPTICON board meeting, Malta, 20. May; Joint STC/ESE ELT meeting, Garching, 15. June; OPTICON executive meeting, Paris, 20. Sep.; ESE ELT meeting, Garching, 30. Sep.; JENAM, OPTICON Telescope Directors Forum, OPTICON Enhancement Activities, Lissabon, Portugal, 6.–10. Sep. (Talk); Laboratory Astrophysics Retreat, Eisenach, 16. Oct. (Talk)

Thomas Henning: SEEDS Collaboration Meeting, Princeton, NJ, USA, 5.–9. July; DIGIT Meeting, Austin, TX, USA, 8.–12. Nov.

Tom Herbst: “JWST and the ELTs: An Ideal Combination”, ESO Garching, 13.–16. Apr.; “Adaptive Optics, Large Telescopes, and Solar Energy”, Kloster Seeon, 31. Oct.–3. Nov. (Talk)

Stefan Hippler: METIS team meeting, Sterrewacht Leiden, The Netherlands, 27.–28. Sep.; GRAVITY consortium progress meeting, SIM, Lissabon, Portugal, 8.–9. March; GRAVITY consortium progress meeting, LESIA, Paris, France, 31. June–1. July; GRAVITY consortium progress meeting, MPE, Garching, 23. Sep.; GRAVITY delta preliminary design review, ESO, Garching, 24. Sep.; GRAVITY technical meeting, ESO, Garching, 2. Dec.; GRAVITY consortium progress meeting, Univ. Cologne, Cologne, 7.–8. Dec.

Jacqueline Hodge: 215th American Astronomical Society Meeting, Washington, DC, USA, 3.–7. Jan. (Talk); Workshop “Observing with ALMA – Early Science”, Grenoble, France, 29. Nov.–1. Dec.

Rory Holmes: SPIE Astronomical Telescopes and Instrumentation, San Diego, CA, USA, 27. June–2. July (Talk, Poster)

Katherine Inskip: “Evolution of galaxies, their central black holes and their large-scale environment”, Potsdam, 20.–24. Sep. (Talk)

Cornelia Jäger: “Zooming in: The cosmos at high resolution”, Splinter meeting – ISM Physics of the interstellar medium, Bonn, 13.–17. Sep. (Talk); Japanese-German Workshop “Dust in planetary systems”, Jena, 27. Sep.–1. Oct. (Poster); Joint meeting: “Paneth Colloquium”

& "The first 10 million years of the solar system", Nördlingen, 27.–30. Oct. (Poster)

Klaus Jäger: Meeting of the scientific Borad of the "International Summer Science School Heidelberg", Palais Graimberg, Heidelberg, 25. Feb., 7. June, 7. Oct.; Meeting of the Rat Deutscher Sternwarten (RDS), Zentrum für Astronomie Heidelberg (ZAH), 18. March; Meeting of the LBT-Beteiligungsgesellschaft (LBTB), Garching, 29. Apr.; Board Meeting of the Astronomische Gesellschaft, Bonn, 13. Sep.; Meeting of the Rat Deutscher Sternwarten (RDS), Bonn, 13. Sep.; Annual Meeting of the Astronomische Gesellschaft "Zooming in: the Cosmos at High Resolution", Bonn, 13.–18. Sep.; Board Meeting of the Astronomische Gesellschaft, Heidelberg, 21. Oct.; Meeting for the Sofja Kovalevskaja-Award winners 2010 of the Humboldt-Foundation, Berlin, 8.–10. Nov.

Knud Jahnke: "What drives the growth of black holes?", Durham, UK, 26.–29. July (Talk)

Viki Joergens: IAU Symposium 270 "Numerical Star Formation", Barcelona, Spain, 31. May–4. June (Poster); Annual Meeting of the Astronomische Gesellschaft, Bonn, 13.–17. Sep.

Katharine Johnston: "The impact of HERSCHEL surveys on ALMA Early Science", ESO Garching, 16.–19. Nov. (Poster); "Observing with ALMA – Early Science", IRAM Grenoble, 29. Nov.–1. Dec.

Jouni Kainulainen: "From Stars to Galaxies", Gainesville, Florida, USA, 6.–10. Apr. (Poster); "Early Phase of Star Formation", Ringberg Castle, 14.–18. June (Poster)

Lisa Kaltenegger: EChO Team Meeting, Utrecht, The Netherlands, Oct.

Alexander Karim: COSMOS AGN working group meeting MPI für Extraterrestrische Physik, Garching, Feb.; Infrared Emission, ISM and Star Formation, MPIA, Heidelberg, Feb.; COSMOS collaboration meeting, University of Hawaii, Honolulu, USA, June; "Challenges in Infrared extragalactic Astronomy II", Univ. Kreta, Agios Nikolaos, Greece, Sep.; "Witnesses of cosmic history", DFG Priority Program 1177, Astrophysikalisches Institut, Potsdam, Sep.; Sub-mm splinter session at Annual meeting of the German Astronomical Society, University of Bonn, Bonn, Sep.; "Galaxy Evolution: Infrared to Millimeter wavelength perspective", Guilin, China, Oct.

Ulrich Klaas: HERSCHEL First Results Symposium (ESLAB 2010), ESTEC, Noordwijk, The Netherlands, 4.–7. May (Talk)

Hubert Klahr: PANETH Colloquium, Nördlingen, Oct. (Talk); research group meeting FOR 759, May (Talk)

Reiner Klement: IAU Symposium 276 "The Astrophysics of Planetary Systems: Formation, Structure, and Dynamical Evolution", Turino, Italy, 11.– 15. Oct. (Talk)

Serge Krasnokutski: 8th International Conference on Low Temperature Chemistry, Yerevan, Armenia, 22.–27. Aug. (Talk)

Oliver Krause: HERSCHEL First Results Symposium, Noordwijk, The Netherlands, 4.–7. May (Talk); "From Stars to Galaxies", Gainesville, Florida, USA, 11.–14. Apr. (Talk); SPIE Astronomical Instrumentation, San Diego, CA, USA, 27. June–2. July (Talk); "HERSCHEL and the formation of stars and planetary systems", Göteborg, Sweden, 6.–9. Sep. (Talk); Cospar Scientific Assembly, Bremen, 18.–25. July (Talk); Zermatt ISM Symposium, Zermatt, Switzerland, 19.–24. Sep. (Talk)

Natalia Kudryavtseva: "From Stars to Galaxies", Gainesville, Florida, USA, 7.–10. Apr. (Poster); "The Origin of Stellar Masses", Tenerife, Canarian Islands, Spain, 18.–22. Oct. (Poster); "In the Spirit of Lyot 2010", Paris, France, 25.–29. Oct. (Poster); VLTI training school, Porquerolles Island, France, 17.–28. Apr. (Poster); MPIA Student Workshop, Norddeich, 7.–14. May (Talk)

Martin Kürster: SPIE Conference Astronomical Instrumentation 2010, San Diego, CA, USA, 27. June–2. July (Poster)

Rolf Kuiper: "From Stars to Galaxies", Gainesville, Florida, USA, 6.–10. Apr. (Poster); IAU Symposium 270: Computational Star Formation, Barcelona, Spain, 31. May–4. June (Talk, Poster); EPoS 2010 (Early Phases of Star Formation), Ringberg Castle, 14.–18. June (Poster); 39th Liege International Astrophysical Colloquium: The multi-wavelength view of hot, massive stars, Liege, Belgien, 12.–16. July (Talk); "Great Barriers in High-mass Star Formation", Townsville, Queensland, Australia, 13.–17. Sep. (Talk); "Frontiers in Computational Astrophysics", Lyon, France, 11.–15. Oct. (Talk)

Ronald Läsker: "Evolution of galaxies, their central black holes and their large-scale environment", Potsdam, 20.–24. Sep. (Poster)

Ralf Launhardt: FRINGE meeting, Jena, 19. July; "HERSCHEL and the formation of stars and planets", Goeteborg, Sweden, 6.–9. Sep. (Talk)

Christian Leipski: HERSCHEL First Results Symposium, ESTEC, Noordwijk, The Netherlands, 4.–7. May (Talk)

Rainer Lenzen: LUCIFER status meeting, Garching, 26. Jan.; GRAVITY meeting, Lissabon, Portugal, 8.–9. March; GRAVITY meeting, Paris, France, 31. May–1. June; SPIE Conference, San Diego, CA, USA, 28. June–2. July; GRAVITY consortium meeting, Garching, 23.–24. Sep.; METIS meeting, Leiden, The Netherlands, 27.–28. Sep.; Kick-off meeting CARMENES, Granada, Spain, 29. Nov.–1. Dec.; GRAVITY progress meeting, Cologne, 7. Dec.

Hendrik Linz: "HERSCHEL Map-Making Review", University of Cardiff, Wales, UK, 8.–9. Feb; "HERSCHEL First Results Symposium" (ESLAB 2010), ESTEC, Noordwijk, Netherlands, 4.–7. May (Poster); "Early Phases of Star Formation (EPOS 2010)", MPG Tagungszentrum, Ringberg Castle, 14.–18. June (Poster); "HERSCHEL and the Formation of Stars and Planets, Särö/Göteborg, Sweden, 6.–9. Sep. (Talk)

Chao Liu: "Galactic Studies with the LAMOST Surveys", Beijing, China, 19.–23. July (Talk)

Mariya Lyubenova: CALIFA Kick-off meeting in Almeria, Spain, 6.–7. June; "Central Massive Objects: The Stellar Nuclei – Black Hole Connection", Garching, 21.–25.

June (Talk); "Why Galaxies Care About AGB Stars", Vienna, Austria, 16.–21. Aug. (Poster)

Andrea Macciò: "Dark Matter in the Universe and Universal Properties of Galaxies: Theory and Observations", Paris, France, 8.–11. June (Talk); "Dark Matter all around", Paris, France, 13.–15. Dec. (Talk)

Nicolas Martin: "A Universe of Dwarf Galaxies", Lyon, France, June (Talk); Pan-STARRS 1 science consortium meeting, Belfast, UK, Sep. (Talk)

Maren Mohler: Annual Meeting of the Astronomische Gesellschaf, Bonn, 13.–17. Sep.

Christoph Mordasini: "Planetary Population Synthesis: The predictive power of planet formation theory.", Ringberg Castle, Nov. (Talk); IAU Symposium 276 "The Astrophysics of Planetary Systems: Formation, Structure, and Dynamical Evolution.", Turino, Italy, Oct. (Talk); Aug. Conference "Detection and dynamics of transiting planets", Observatoire de haute provence OHP, France, May (Talk); "Circumstellar disks and planets – Science cases for the second generation VLTI instrumentation", Kiel (Talk); EGU general assembly 2010, Vienna, Austria, May (Talk); "The Theory and Observation of Exoplanets", KITP, UCSB, Santa Barbara, USA, March (Talk)

Vianak Naranjo: SPIE Astronomical Telescopes and Instrumentation, San Diego, CA, USA, 27. June–2. July

Markus Nielbock: HERSCHEL Calibration Steering Group Meeting #24, RAL, Didcot, UK, 3. Feb. (Talk); HERSCHEL SPIRE/PACS Map Making Workshop, Cardiff University, UK, 8.–9. Feb.; HERSCHEL PACS Performance Verification Review, MPE, Garching, 17.–19. Feb. (Talk); ESLAB 2010: HERSCHEL First Results Symposium, ESTEC, Noordwijk, The Netherlands, 4.–7. Apr.; HERSCHEL Calibration Steering Group Meeting #25, MPIA, 10. May; "Early Phases of Star Formation 2010", Ringberg Castle, 14.–18. June (Talk, Poster); "HERSCHEL and the formation of stars and planetary systems", Göteborg/Särö, 6.–9. Sep. (Poster); HERSCHEL PACS Photometer ICC Workshop, CEA, Saclay, France, 14.–17. Sep. (Talk); HERSCHEL PACS ICC Meeting, Konkoly Observatory, Budapest, Ungarn, 6.–8. Oct. (Talk); MPIA PSF Group Retreat, Löwenstein, 27.–29. Oct. (Talk); HERSCHEL Calibration Workshop, and HERSCHEL Calibration Steering Group Meeting #26, EsaC, Villafranca, Spain, 13.–15. Dec. (Talk)

Nikolay Nikolov Nikolov: "Detection and dynamics of transiting exoplanets", Observatoire de Haute-Provence, France, 23.–27. Aug. (Poster)

Dading Nugroho: "Evolution of galaxies, their central black holes and their large-scale environment", Potsdam, 20.–24. Sep. (Poster); "What drives the growth of black holes?", Durham/UK, 26.–29. July (Poster)

Christiaan Ormel: "Evolving Theory for Planet Formation", Ishigaki island, Japan, 20.–25. June (Talk); "Dust in planetary systems", Jena, 26. Sep.–1. Oct. (Talk); "Planetary Population Synthesis: The Predictive Power of Planet Formation Theory", Ringberg Castle, 29. Nov.–3. Dec. (Talk)

Diethard Peter: SPIE Astronomical telescopes and instrumentation 2010, San Diego, CA, USA, 27. June–2. July (Talk, Poster); ARGOS final design review, Tucson, AZ, USA, 26.–29. March (Talk)

Karsten Potrick: European Summer School NanoLum, Porquerolles, France, 28. June–1. July (Talk)

Axel M. Quetz: Annual Meeting of the Astronomische Gesellschaft, Bonn, 14.–15. Sep.

Natalie Raettig: IAU Symposium 276, Turino, Italy, 10.–16. Oct. (Poster); PSF Retreat: 27.–29. Oct. (Talk)

Sarah Ragan: "From Stars to Galaxies", Gainesville, FL, USA, 7.–10. Apr. (Talk); "Early Phases of Star Formation", Ringberg Castle, 14.–18. June (Poster); "HERSCHEL and formation of stars and planetary systems", Göteborg, Sweden, 6.–9. Sep. (Poster); "The impact of HERSCHEL surveys on ALMA Early Science", Garching, 16.–19. Nov. (Talk)

Hans-Walter Rix: "Infrared Emission, Interstellar Medium & Star Formation", 22.–24. Feb.; Sixth Harvard-Smithsonian Conference in Theoretical Astrophysics, Harvard University, 9.–12. May; EUCLID Consortium Meeting, IAF Paris, 25.–26. May; KINGFISH Meeting, Ringberg Kreuth, 11.–17. July; Darkness Visible Cambridge Conference, 2.–3. Aug.; Review Talk "SPP Conference", Potsdam, 24. Sep.; 25th Texas Symposium on Relativistic Astrophysics, Heidelberg, 9. Dec.

Boyke Rochau: "From Stars to Galaxies", University of Florida, Gainesville, Florida, USA, 7.–10. Apr. (Poster);

IAU Symposium 270, Barcelona, Spain, 31. May–4. June (Poster)

Maria Vicroria Rodriguez-Ledesma: "Cool Stars XVI", Seattle, 28. Aug.–5. Sep. (Poster)

Gaël Rouillé: "PAHs and the Universe", Toulouse, France, 31. May–4. June (Poster)

Karin Sandstrom: 215th American Astronomical Society Meeting, Washington DC, USA, 3.–7. Jan. (Poster); "Infrared Emission, ISM and Star Formation", Heidelberg, 22.–24. Feb. (Talk); "From Stars to Galaxies", Gainesville FL USA, 7.–10. Apr. (Talk); "PAHs and the Universe" Toulouse, France, 31. May–4. June (Talk); "Molecules in Galaxies" Oxford UK, 26.–30. Jul. (Talk)

Mark Sargent: "Infrared Emission, ISM & Star Formation (IR10)", MPIA, Heidelberg, 22.–24. Feb. (Talk); SKA 2010, Manchester, UK, 22.–25. March (Talk); COSMOS Team Meeting, Honolulu, Hawaii, USA, 7.–10. June (Talk); ALMA HERSCHEL Workshop, Garching, 16.–19. Nov. (Poster)

Silvia Scheithauer: MIRI European Consortium Meeting, Marseille, France, 26.–28. May

Eva Schinnerer: "Infrared Emission, Interstellar Medium and Star Formation", MPIA, 22.–24. Feb.; "Scientific Opportunities For new Instrumentation, Asilomar 2010", SOFIA workshop, Asilomar, USA, 7.–8. June (Talk); "Star Formation in Galaxies: From Recipes to Real Physics", Aspen, USA, 29. Aug.–12. Sep.; "The impact of HERSCHEL surveys on ALMA Early Science", ESO ALMA/HERSCHEL workshop, Garching, 16.–19. Nov. (Talk)

Markus Schmalzl: 215th AAS Meeting, Washington, DC, USA, 3.–7. Jan. (Poster); "HERSCHEL and the formation of stars and planetary systems", Gothenburg, Sweden, 6.–9. Sep. (Poster); "The impact of HERSCHEL surveys on ALMA Early Science", Garching, 16.–19. Nov. (Poster)

Kasper Borello Schmidt: ELIXIR School: The JWST/NIRSPEC project, EADS/Astrium GmbH, Ottobrunn, 31. May–2. June; "The First Galaxies, Quasars and Gamma-Ray Bursts", Pennsylvania State University, State College, PA, USA, 6.–10. June (Poster); Pan-STARRS1 Science Consortium Meeting, Queens University, Belfast, Northern Ireland, 30. Aug.–3. Sep. (Talk); Summer School: "First Stars & Cosmic Reionization", IMPRS Heidelberg, Heidelberg, 6.–10. Sep.; 3D-HST meeting, University of Yale, New Haven, CT, USA, 13.–15. Sep.; ELIXIR annual meeting, IAP, Paris, France, 3.–5. Nov.; Slitless Spectroscopy Workshop, STScI, Baltimore, MD, USA, 15.–16. Nov.

Torsten Schmidt: BONSAI Symposium: "Breakthroughs in nanoparticles for bio-imaging", Frascati, Italy, 8.–9. Apr. (Talk); European Summer School NanoLum, Porquerolles, France, 28. June–1. July (Talk)

Jürgen Schreiber: PACS software developer meeting at IPAC, Pasadena, 18.–23. Jan.; PACS Instrument control center colocation at MPE, Garching, 12.–14. Apr.; PACS software developer meeting at KU, Leuven, 31. May–3. June; PACS Instrument control center colocation at Konkoly observatory, Budapest: 6.–9. Oct.; MIRI software developer meeting at STSCI, Baltimore, USA, 28. Sep.–2. Oct.

Andreas Schruba: "From Stars to Galaxies", Gainesville, USA, 7.–10. Apr. (Poster); "Molecules in Galaxies", Oxford, UK, 26.–30. July (Talk)

Tim Schulze-Hartung: PRIMA Science Team Meeting, Genf, Switzerland, 10.–11. June; "Zooming in: The Cosmos at High Resolution", Bonn, 13.–17. Sep. (Poster); PRIMA Science Team Meeting, Garching, 25.–26. Nov.

Dmitry Semenov: "Chemical Evolution of Protoplanetary Disks", ITA, Feb. (Talk); Paneth Colloquium of the DFG SPP 1385, Oct. (Poster); Astrochemistry meeting in Eisenach, Oct. (Talk)

Johny Setiawan: "Planetary Systems beyond the Main Sequence", Bamberg, 11.–14. Aug. (Talk); IAU Symposium 276 "The Astrophysics of Planetary Systems: Formation, Structure, and Dynamical Evolution", Turino, Italy, 11.–15. Oct. (Poster)

Mathias Steglich: "PAHs and the Universe", Toulouse, France, 31. May–4. June (Poster)

Jürgen Steinacker: "Stormy Cosmos: The Evolving ISM from SPITZER to HERSCHEL and Beyond", Pasadena, USA, 1.–4. Nov. (Talk); "The Early Phase of Star Formation EPoS 2010", Ringberg Castle, 14.–18. June (Talk)

Micaela Stumpf: 215th Meeting of the American Astronomical Society (AAS), Seattle, USA, 3.–7. Jan. (Poster); ESO Workshop "JWST and the ELTs: an ideal combination", Garching, 13.–16. Apr. (Poster); "Cool Stars 16", Seattle, USA, 28. Aug.–2. Sep. (Poster)

Amelia Stutz: "From Stars to Galaxies", Gainesville, Florida, Apr. (Poster); HERSCHEL First Results Symposium (aka ESLAB 2010), ESTEC, Noordwijk, 4.–7. May (Poster); "HERSCHEL and the Formation of Stars and Planetary Systems", Göteborg, Sweden, 6.–9. Sep. (Talk); "The Impact of HERSCHEL Surveys on ALMA Early Science", Garching, 17.–19. Nov. (Talk)

Jochen Tackenberg: "Great Barriers in High-mass star formation", Townsville, Queensland, Australia, 13.–17. Sep. (Poster)

Christian Thalmann: "Spirit of Lyot conference 2010", Paris, France, 25.–29. Oct. (Talk)

Ana Lucia Uribe: IAU Symposium No. 276 "The Astrophysics of Planetary Systems",Turino, Italy, 11.–15. Oct.

Roy van Boekel: EChO Meeting, Barcelona, Spain, 30. Sep.–1. Oct.; EChO meeting, Utrecht, The Netherlands, 4.–5. Nov.; SPHERE disks meeting, Zürich, Switzerland, 22.–23. Nov.

Glenn van de Ven: "Early-type Dwarf Galaxies: Origin, Evolution, Characteristics", Heidelberg, 18.–20. Oct. (Talk); CALIFA Kick-Off Meeting, Almeria, Spain, 7.–8. June (Talk)

Tessel van der Laan: "Molecules in Galaxies", Univ. Oxford, UK, 26.–30. July (Poster); "Central Massive Objects: The stellar nuclei – Black hole connection", ESO, Garching, 22.–25. June (Talk); "Puzzles of Galactic Nuclei", MPE, Garching, 28.–30. June; IR10 workshop, MPIA, 22.–24. Feb. (Poster); GC retreat, Heilbronn, 21.–23. Apr. (Talk)

Arjen van der Wel: Seminar at Yale University, New Haven, USA, 26. Jan. (Talk); Seminar at NOAO, Tucson, AZ, USA, 29. Jan. (Talk); Seminar at University of Texas, Austin, USA, 11. Feb. (Talk); Seminar at DARK Institute, Kopenhagen, Denmark, 29. May (Talk); "Galaxies in the Distant Universe: Dynamics, Gas, and Early Evolution", Ringberg Castle, 17.–21. May (Talk); "Evolution of galaxies, their central black holes and their large-scale environment", Potsdam, 20.–24. Sep. (Talk)

Fabian Walter: JWST MIRI European consortium meeting, Madrid, Spain, Jan. (Talk); HERSCHEL KINGFISH Science Team Meeting, Heidelberg, Feb.; HERACLES Team Meeting, Heidelberg, Feb. (Talk); JWST MIRI European consortium meeting, Paris, March (Talk); LITTLE THINGS Team Meeting, Heidelberg, March (Talk); "Galaxies in the Distant Universe", Ringberg Castle, May (Talk); "ALMA band 5", Rom, Italy, May (Talk); HERSCHEL KINGFISH Science Team Meeting, Ringberg Castle, July (Talk); "Molecules in Galaxies", Oxford, July (Talk); "Star Formation in Galaxies: From Recipes to Real Physics", Aspen, CO, USA, Sep.; JWST MIRI European consortium meeting, Ringberg Castle, Oct.; "The Impact of HERSCHEL Surveys on ALMA Early Science", Garching, Nov. (Talk)

Yujin Yang: "Witnesses of Cosmic History: Formation and Evolution of Black-holes, Galaxies and their Environment", Potsdam, 20.–24. Sep. (Poster)

Svitlana Zhukovska: "Dusty visions 2010: A workshop on Dust Spectroscopy and Dust Astronomy", Göttingen, 14.–16. July (Talk); "Why Galaxies care about AGB stars II", Vienna, Austria, 16.–20. Aug.; External retreat of Laboratory Astrophysics group, Eisenach, 15.–16. Oct. (Talk); Retreat of PSF department, Löwenstein, 27.–29. Oct.

Invited Talks, Colloquia

Coryn Bailer-Jones: JENAM 2010, "Star Clusters in the Era of Large Surveys", Lissabon, Portugal, 6.–10. Sep. (Talk)

Henrik Beuther: EPoS 2010 (Talk); "From Stars to Galaxies – Connecting our understanding of star and galaxy formation", Gainsville, Florida, 7.–10. Apr. (Talk)

Arjan Bik: Jacobs University, Bremen, 10. March (Colloquium); "Steady jets and transient jets", Bonn, 6.–7. Apr. (Talk); Dutch ISM/ICM meeting, Amsterdam, The Netherlands, 2. June (Talk); IAU Symposium 275: "Jets at all scales", Buenos Aires, Argentinia, 13.–17. Sep. (Talk); Stockholm University, Stockholm, Sweden, 22. Oct. (Colloquium)

Tilman Birnstiel: CfA Harvard, Cambridge, USA, 3. Nov. (Talk); University of Colorado, Boulder, USA, 12. Nov. (Talk); University of Michigan, Ann Arbor, USA, 16. Nov. (Talk); ITA, Heidelberg, 8. Dec. (Talk)

Mauricio Cisternas: Harvard CfA, Cambridge, MA, USA, 4. June (Colloquium); Cambridge, MA, USA, 4. June (Colloquium)

David Martinez Delgado: "Star Clusters in the Era of Large Surveys" JENAM 2010 Joint European and National Astronomy Meeting, Lissabon, Portugal, 6.–10. Sep. (Talk); IX Scientific Meeting of the Spanish Astronomical Society, Madrid, Spain, 13.–17. Sep. (Talk); Kapteyn Astronomical Institute, Groningen, The Netherlands, 4. Oct. (Colloquium); Astrophysical Institute Postdam, Postdam, 5. March (Colloquium); Department of Astronomy, University of Florida, 3. Nov. (Talk)

Cornelis Dullemond: ESO Workshop "Origin and Fate of the Sun", Garching, 2.–5. March (Talk); "Evolving Theory for Planet Formation", Ishigaki, Japan, 20.–26. June (Talk); Ringberg workshop on Planet Synthesis, Ringberg, 29. Nov.–3. Dec. (Talk); Cambridge University, DAMTP, 10. May (Colloquium); Munich Joint Astronomical Colloquium, Garching, 28. Jan. (Colloquium)

Gael Dumas: IAA – Universidad de Granada, Granada, Spain, 17. May (Talk); Astrophysics Research Institute, Liverpool, UK, 9. July (Talk)

Christian Fendt: "Accretion and outflow in black hole systems", Kathmandu, Nepal, 11.–15. Oct. (Talk); IAU Symposium 275 "Jets at all scales", Buenos Aires, Argentinien, 13.–17. Sep. (Talk); "Steady jets and transient jets", Bonn, 6.–7. Apr. (Talk); Jacobs Universität, Bremen, 10. March (Colloquium)

Anna Gallazzi: Institute of Astronomy, Cambridge, UK, 27. Jan. (Talk)

Bertrand Goldman: Observatoire de Strasbourg, 18. June (Colloquium);

Universtät Göttingen, 19. Jan. (Colloquium); "X-shooter 2010: in memory of R. Pallavicini", Como, Italy, 19.–22. Oct. (Talk)

Dimitrios A. Gouliermis: Universitäts-Sternwarte Munich, 14. July (Talk); University of Illinois at Urbana-Champaign, 15. Nov. (Talk)

Roland Gredel: Laboratory Astrophysics group at Jena university, Jena, 11. June (Talk); Physikalisches Institut Freiburg university, Freiburg, 18. Oct. (Talk)

Joseph Hennawi: "Key Issues in High-redhsift Galaxy/Black Hole Evolution in the ALMA/JWST Era", Beijing, China, 29. May–4. June (Talk); University of Cambridge, 28. Oct. (Colloquium), Joint Astronomical Colloqium, Universität Heidelberg, 2. Nov. (Colloquium)

Thomas Henning: DPG-Tagung, Bonn, 15.–19. March (Plenary Lecture); Cost Action "CM 805", Boppard, 9.–12. May (Talk); German-Chinese Workshop, Kiel, 26.–30. July (Talk); IMA 2010, Budapest, 26.–29. Aug. (Plenary Lecture); "Great Barriers in High Mass Star Formation", Townsville, 13.–17. Sep. (Talk); Univ. of Texas at Austin, 9. Oct. (Kolloqium); Innsbruck, 19. Oct. (Colloquium); "The role of turbulence in the formation of planetesimals", German-Japanse Workshop, Jena, Oct. (Talk); Disk Workshop, Utrecht, 4.–5. Nov. (Talk); "Adaptive Optics, Large Telescopes and Solar Energy", Seeon, 31. Oct.–2. Nov. (Talk)

Tom Herbst: "Circumstellar disks and planets – Science cases for next generation optical/infrared interferometers", Kiel, 26.–28. May (Talk); SPIE Meeting, San Diego, USA, 27. June–2. July (Talk)

Friedrich Huisken: Workshop on Bio-Imaging with Smart Functional Nanoparticles, Padua, Italy, 25.–26. Jan. (Talk); NanoLum Summer School, Porquerolles, France, 28. June–1. July (Talk); 27th International Symposium on Rarefied Gas Dynamics, Asilomar, USA, 10.–16. July (Talk)

Cornelia Jäger: "PAHs and the Universe", Toulouse, France, 31. May–4. June (Talk); Bereichsseminar am Fritz-Haber-Institut, Berlin, 14. June (Colloquium); "Conditions and Impact of Star Formation: New results with HERSCHEL and beyond", Zermatt, Switzerland, 19.–24. Sep. (Talk); "Synchrotron Radiation in Earth, Space & Planetary Science – Exploiting the UK's newest facility, Diamond Light Source", Oxfordshire, UK, 10.–11. Nov. (Talk)

Knud Jahnke: "Evolution of galaxies, their central black holes and their large-scale environment", Potsdam, 20.–24. Sep. (Talk); ESF Exploratory Workshop "Cosmogony of AGN", Brindisi, Italy, 31. Aug.–4. Sep. (Talk); 460. Wilhelm and Else Heraeus Seminar: "Black Holes", Bad Honef, 7.–11. June (Talk); 74. anual meeting of the Deutsche Physikalische Gesellschaft, Bonn, 15.–19. March (Talk)

Jouni Kainulainen: University of Exeter, School of Physics, Exeter, UK, 24. Nov. (Colloquium)

Lisa Kaltenegger: IAUS 276, Turino, Italy, Oct. (Talk); Royal Society Meeting, Milton Keynes, UK, Sep. (Talk);

Univ. Montreal, Montreal, Canada, Sep. (Colloquium); Harvard Univ., Origins of Life Initiative, Boston, USA, 15. Sep. (Colloquium); Hauskolloquium MPIA, Germany, Oct. (Colloquium); "Planetary Population Synthesis: The Predictive Power of Planet Formation Theory", Ringberg Castle, 3. Dec. (Talk)

Alexander Karim: IPAC / Caltech Lunch Seminar, California Institute of Technology, Pasadena, USA, 26. May (Colloquium)

Hubert Klahr: "Radiation Hydro of turbulence in circumstellar disks" Frontiers in Computational Astrophysics, Lyon, France, Oct. (Talk); "The role of turbulence in the formation of planetesimals", German-Japanse Workshop, Jena, Oct. (Talk); "The role of turbulence in the formation of planetesimals" Univ. of Colorado, Boulder, USA, Nov. (Colloquium); "The role of turbulence in the formation of planetesimals" AMNH, New York, USA, Dec. (Colloquium); "Conditions for Disk Fragmentation Planets – Planetary Population Synthesis: The Predictive Power of Planet Formation Theory", Ringberg Castle, Nov. (Talk)

Oliver Krause: Cospar Scientific Assembly, Bremen, 18.–25. July (Talk); Heidelberg Joint Astronomical Colloquium, 9. Nov. (Colloquium)

Dietrich Lemke: Hochschule Mannheim, Physics Colloquium, May (Talk);

Hua-Bai Li: "Magnetic Fields: From Core Collapse to Young Stellar Objects", The University of Western Ontario, London, Ontario, Canada, 17.–19. May (Talk); "Cosmic magnetism: From stellar to intergalactic scales", ANTF/AAO, Kaima, Australia, 7.–11. June (Talk)

Chao Liu: "Galactic Studies with the LAMOST Surveys", Beijing, China, 19.–23. July (Talk)

Andrea Macciò: Kavli Institute for Cosmology, Cambridge, UK, 25. Jan. (Talk); Niels Bohr Academy, Kopenhagen, Denmark, 22. Feb. (Talk); University of Stockholm, Stockholm, Sweden, 15. Oct. (Talk)

Nicolas Martin: "Chemistry, dynamics and structure of the Milky Way", Kavli Institute for Astronomy and Astrophysics, Beijing, China, July (Talk); Observatoire de Strasbourg, Straßburg, France, Feb. (Colloquium); Durham University, Institute for Computational Cosmology, Durham, UK, Oct. (Colloquium); Kapteyn Institute, Groningen, The Netherlands, Nov. (Colloquium)

Christoph Mordasini: "Comparing planet formation theory and extrasolar planet observations", CAUP, Univ. Porto, Porto, Portugal, Dec. (Colloquium); "Planetary population synthesis: The predictive power of planet formation theory", Ringberg Castle, Nov. (Talk); IAU Symposium 276, Turino, Italy, Oct. (Talk); "Detection and dynamics of transiting planets", OHP, France, Aug. (Talk); "Circumstellar disks and planets – Science cases for the second generation VLTI instrumentation", Kiel, May (Talk); EGU general assembly 2010, Vienna, Austria, May (Talk); KITP, UCSB, Santa Barbara, USA, March (Talk)

Christiaan Ormel: "The dust in planetary systems", Univ. Jena, Jena, 27. Sep.–1. Oct. (Talk); Universität Bern, Bern, Switzerland, 26. May (Colloquium)

Hans-Walter Rix: Kapteyn Institute Groningen, The Netherlands, 19. Feb. (Colloquium); Johns Hopkins University, Baltimore, USA, 2.–5. March (Colloquium); Space Telescope Science Institute, Baltimore, USA, 2.–5. March (Colloquium); "How tiny can Galaxies be?", IAS, 16. Nov. (Colloquium); Studiums Generale: "Wie es Licht wurde im Universum", Stuttgart, 1. Dec. (Talk)

Eva Schinnerer: Heidelberg Joint Astronomical Colloquium, Heidelberg, 5. May (Colloquium); "Scientific Opportunities for new Instrumentation", Asilomar 2010, SOFIA workshop, Asilomar, USA, 7. June (Talk); Universitätssternwarte, Universität Hamburg, 11. June (Colloquium); NRAO, Socorro, 25 Aug. (Talk); INAF, Osservatorio Astronomico di Roma, Monte Porzio, Italy, 14.–15. Oct. (2 Talks)

Aurora Sicilia-Aguilar: ESA/ESTEC, Noordwijk, The Netherlands, 23. Apr. (Talk); Universidad Autonoma de Madrid, Madrid, Spain, 2. June (Talk)

Kester Smith: "Extragalactic Science with GAIA", IAP, Paris, France, 14.–16. June (Talk)

Jakob Staude: Dipartimento di Astronomia, Università di Padova, 2. Jan. (Talk)

Jürgen Steinacker: "WittFest: Origins & evolution of dust", Toledo, US, 10.–12. Oct. (Talk); IAU Symposium 270, Barcelona, Spain, 31. May–4. June (Talk); CEA Saclay Astrophysics Division Seminar, Saclay, France, 28. Jan. (Talk)

Christian Thalmann: Anton Pannekoek Institute, Amsterdam, The Netherlands, 19. May (Colloquium)

Glenn van de Ven: Astrophysics Institute Potsdam, Postdam, 26. Nov. (Colloquium); Stockholm University, Stockholm, Sweden, 26. Oct. (Colloquium); Instituto de Astrofsíca de Canarias, Teneriffe, Spain, 21. Sep. (Colloquium)

Fabian Walter: "Massive Galaxies Over Cosmic Time 3", Tucson, AZ, USA, Nov. (Talk)

Yujin Yang: "Opening New Frontiers with the Giant Magellan Telescope", Seoul, Corea, 4.–6. Oct. (Talk)

Svitlana Zhukovska: 17th Young Scientists' Conference on Astronomy and Space Physics, Kyiv, Ukraine, 26. Apr.–1. May (Talk); Laboratory Astrophysics seminar, Jena, 22. Jan. (Talk); JBCA, Manchester, UK, 25. Jan. (Talk); Kirchhoff Institute for Physics, Heidelberg, 11. Oct. (Talk);

Stefano Zibetti: Leiden Observatory, Leiden, The Netherlands, 9. Feb. (Colloquium), Dark Cosmology Centre, Niels Bohr Institute, University of Copenhagen, Kopenhagen, Denmark, 12. Feb. (Colloquium)

Talk Series

H.-W. Rix: Galaxy Summerschool, Bad Honnef

Popular Talks

Henrik Beuther: "Die Geburt der Sterne", Max-Planck-Haus, Munich, 3. Nov.

Tilman Birnstiel: "Astronomie am MPIA", Hermann-Staudinger Gymnasium, Erlenbach am Main, 2. June

Leonard Burtscher: "Aktive Galaxien – Leuchttürme des Universums", Planetarium Mannheim, 8. June

Christian Fendt: "Kosmische Düsentriebwerke – Jets von jungen Sternen und schwarzen Löchern", Sternfreunde Nordenham e.V., Nordenham, 10. March; "Kosmische Düsentriebwerke – Jets von jungen Sternen und schwarzen Löchern", Olbers-Gesellschaft e.V., Bremen, 9. March

Roland Gredel: "Giganten für den Blick ins All – Die neuen Riesenteleskope", Rüsselsheimer Sternfreunde, 7. May; "Das Europäische Riesenteleskop E-ELT – von der Idee zur Verwirklichung", Planetarium Mannheim, 1. Oct.

Tom Herbst: "Building the Biggest Telescopes in the World", within a guided tour for a grade of Grammar School at the MPIA, 1. Oct.

Stefan Hippler: "Die Jagd nach fremden Welten", Robert-Mayer-Sternwarte, Heilbronn, 12. Nov.

Klaus Jäger: "Schöne Bilder, die Wissen schaffen – Lehrreiches von Hubble und Co.", Public Lecture, Robert-Mayer-Sternwarte, Heilbronn, 12. Feb.; "Der Himmel im Computer – Virtuelle Planetarien", Girls' Day 2010, MPIA, 22. Apr.; "Geheimnisvolle Quasare – der Lösung eines Rätsels auf der Spur", Planetarium Stuttgart, 6. May; "Eine Legende hat Geburtstag – 20 Jahre Astronomie mit dem Hubble-Weltraumteleskop", Talk within the lectures "Astronomie am Sonntag Vormittag", MPIA, 13. June; "Geheimnisvolle Quasare – der Lösung eines Rätsels auf der Spur", Planetarium Nürnberg, 5. Oct.; "Scharfblick und Weitsicht – Erstaunliche Fakten aus der Arbeit des MPIA", MPIA, 17. Dec.

Viki Joergens: "Braune Zwerge: Gescheiterte Sterne oder Superplaneten?", Talk within the lectures "Astronomie am Sonntag Vormittag", MPIA, 4. July

Lisa Kaltenegger: Renaissance weekend, Aspen, Colorado, USA, Sep.

Hubert Klahr: "Faszination Weltall – Planeten, Sterne, schwarze Löcher", Hannah-Arendt-Gymnasium, Haßloch, 5. Oct.

Oliver Krause: "Supernova-Lichtechos – Zeitreise in die Vergangenheit", Starkenburg-Sternwarte, Heppenheim, 26. Jan.; "Das Weltraumteleskop HERSCHEL – Europas neues Fenster ins All", Planetarium Mannheim

Dietrich Lemke: "HERSCHEL – Das erste Jahr", Starkenburg Sternwarte, Apr.; "HERSCHEL – The European Large Space Telescope", Nordenham Astronomy Amateurs, May; "Astronomische Teleskope – Geschichte und Zukunft einer Entdeckungsmaschine", Bayerische Staatsoper / Max-Planck-Gesellschaft, Munich, Nov.; "Aurorae and the Sun", "Surveying the Earth – The Struve Meridian", "Astronomical Telescopes – History and Future", Talks during a polar sea trip of the Hurtigrutenschiff "Polarlys", Oct.

Klaus Meisenheimer: "Das größte optische Teleskop der Erde", AME 2010, Villingen-Schwenningen, 18. Sep.

Markus Nielbock: "HERSCHEL & Planck – Europas neue Weltraumteleskope", Planetarium Erkrath-Hochdahl, 28. Jan.; "HERSCHEL & Planck – Europas neue Weltraumteleskope", Volkssternwarte und Planetarium Recklinghausen, 10. March; "HERSCHEL – Europas neues Weltraumteleskop", Engadiner Astronomiefreunde, Gemeindeschule St. Moritz, Switzerland, 24. Apr.

Silvia Scheithauer: "Wo Sonne, Mond und Sterne ihr zu Hause haben", Kinderuniversität Bretten, 19. Apr.; "Das MPIA stellt sich vor", Special guided tour for the Kinderuniversität Bretten, 18. June

Johny Setiawan: "Geburt, Leben und Tod eines Sonnensystems", Talk within the lectures "Astronomie am Sonntag Vormittag", MPIA, 20. June

Jakob Staude: "Das Haus der Astronomie", AME 2010, Villingen-Schwenningen, 18. Sep.

Jochen Tackenberg: Talk within the first occupational area day am Heinrich-Heine-Gymnasium, Cologne, 6. Nov.

Publications

In Journals with Referee System

Acke, B., J. Bouwman, A. Juhász, T. Henning, M. E. van den Ancker, G. Meeus, A. G. G. M. Tielens and L. B. F. M. Waters: Spitzer's view on aromatic and aliphatic hydrocarbon emission in Herbig Ae stars. The Astrophysical Journal 718, 558-574 (2010)

Albrecht, S., A. Quirrenbach, R. N. Tubbs and R. Vink: A new concept for the combination of optical interferometers and high-resolution spectrographs. Experimental Astronomy 27, 157-186 (2010)

Alibert, Y., C. Broeg, W. Benz, G. Wuchterl, O. Grasset, C. Sotin, C. Eiroa, T. Henning, T. Herbst, L. Kaltenegger, A. Léger, R. Liseau, H. Lammer, C. Beichman, W. Danchi, M. Fridlund, J. Lunine, F. Paresce, A. Penny, A. Quirrenbach, H. Röttgering, F. Selsis, J. Schneider, D. Stam, G. Tinetti and G. J. White: Origin and formation of planetary systems. Astrobiology 10, 19-32 (2010)

Andrae, R., P. Melchior and M. Bartelmann: Soft clustering analysis of galaxy morphologies: a worked example with SDSS. Astronomy and Astrophysics 522, A21 (2010)

André, P., A. Men'shchikov, S. Bontemps, V. Könyves, F. Motte, N. Schneider, P. Didelon, V. Minier, P. Saraceno, D. Ward-Thompson, J. di Francesco, G. White, S. Molinari, L. Testi, A. Abergel, M. Griffin, T. Henning, P. Royer, B. Merín, R. Vavrek, M. Attard, D. Arzoumanian, C. D. Wilson, P. Ade, H. Aussel, J. P. Baluteau, M. Benedettini, J. P. Bernard, J. A. D. L. Blommaert, L. Cambrésy, P. Cox, A. di Giorgio, P. Hargrave, M. Hennemann, M. Huang, J. Kirk, O. Krause, R. Launhardt, S. Leeks, J. Le Pennec, J. Z. Li, P. G. Martin, A. Maury, G. Olofsson, A. Omont, N. Peretto, S. Pezzuto, T. Prusti, H. Roussel, D. Russeil, M. Sauvage, B. Sibthorpe, A. Sicilia-Aguilar, L. Spinoglio, C. Waelkens, A. Woodcraft and A. Zavagno: From filamentary clouds to prestellar cores to the stellar IMF: Initial highlights from the Herschel Gould Belt Survey. Astronomy and Astrophysics 518, L102 (2010)

Andrews, S. M., I. Czekala, D. J. Wilner, C. Espaillat, C. P. Dullemond and A. M. Hughes: Truncated disks in TW Hya association multiple star systems. The Astrophysical Journal 710, 462-469 (2010)

Andrews, S. M., D. J. Wilner, A. M. Hughes, C. Qi and C. P. Dullemond: Protoplanetary disk structures in Ophiuchus. II. Extension to fainter sources. The Astrophysical Journal 723, 1241-1254 (2010)

Antonuccio-Delogu, V., A. Dobrotka, U. Becciani, S. Cielo, C. Giocoli, A. V. Macciò and A. Romeo-Veloná: Dissecting the spin distribution of dark matter haloes. Monthly Notices of the Royal Astronomical Society 407, 1338-1346 (2010)

Aravena, M., F. Bertoldi, C. Carilli, E. Schinnerer, H. J. McCracken, M. Salvato, D. Riechers, K. Sheth, V. Sm□lcić, P. Capak, A. M. Koekemoer and K. M. Menten: Environment of Mambo galaxies in the Cosmos field. The Astrophysical Journal 708, L36-L41 (2010)

Aravena, M., C. Carilli, E. Daddi, J. Wagg, F. Walter, D. Riechers, H. Dannerbauer, G. E. Morrison, D. Stern and M. Krips: Cold molecular gas in massive, star-forming disk galaxies at $z = 1.5$. The Astrophysical Journal 718, 177-183 (2010)

Araya, E. D., P. Hofner, W. M. Goss, S. Kurtz, A. M. S. Richards, H. Linz, L. Olmi and M. Sewiło: Quasi-periodic formaldehyde maser flares in themassive protostellar object Iras 18566+0408. The Astrophysical Journal Letters 717, L133-L137 (2010)

Arold, M., F. Piuzzi, C. Jäger and F. Huisken: Silicon nanocrystals as matrix material for the desorption of biomolecule-water complexes. Chemical Physics Letters 484, 100-103 (2010)

Bacmann, A., E. Caux, P. Hily-Blant, B. Parise, L. Pagani, S. Bottinelli, S. Maret, C. Vastel, C. Ceccarelli, J. Cernicharo, T. Henning, A. Castets, A. Coutens, E. A. Bergin, G. A. Blake, N. Crimier, K. Demyk, C. Dominik, M. Gerin, P. Hennebelle, C. Kahane, A. Klotz, G. Melnick, P. Schilke, V. Wakelam, A. Walters, A. Baudry, T. Bell, M. Benedettini, A. Boogert, S. Cabrit, P. Caselli, C. Codella, C. Comito, P. Encrenaz, E. Falgarone, A. Fuente, P. F. Goldsmith, F. Helmich, E. Herbst, T. Jacq, M. Kama, W. Langer, B. Lefloch, D. Lis, S. Lord, A. Lorenzani, D. Neufeld, B. Nisini, S. Pacheco, J. Pearson, T. Phillips, M. Salez, P. Saraceno, K. Schuster, X. Tielens, F. F. S. van der Tak, M. H. D. van der Wiel, S. Viti, F. Wyrowski, H. Yorke, A. Faure, A. Benz, O. Coeur-Joly, A. Cros, R. Güsten and L. Ravera: First detection of ND in the solar-mass protostar Iras 16293-2422. Astronomy and Astrophysics 521, L42 (2010)

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