Max Planck Institute for Astronomy

Heidelberg-Königstuhl

Max-Planck-Institut für Astronomie Heidelberg
Max Planck Institute for Astronomy Heidelberg

Annual Report 2011

Cover Picture:

The “Haus der Astronomy” (House of Astronomy) was inaugurated in November 2011, only three years after its foundation in 2008 by the Max Planck Society and the Klaus Tschira Foundation (see chapter V for more information).

Its form is inspired from the spiral galaxy Messier 51 in the constellation Canes Venatici, called the whirlpool galaxy. This unique center for astronomy education and outreach on the MPIA campus hosts also the volunteer association Astronomieschule e.V. und the editorial offices of the popular astronomy magazine “Sterne und Weltraum”, which has been produced on the Königstuhl since 1962.

Credits: Swen Carlin, Heidelberg

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Staff: By the end of 2011, a staff of 290 was employed at MPIA (including externally funded positions). This includes 212 scientists, of which 74 were junior and visiting scientists, and 60 were PhD students.

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Preface

This Annual Report is intended for our colleagues worldwide as well as for the interested public.

It describes in particular 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 and some of the instrumentation projects. Furthermore, some other activities and highlights of the life at the institute are presented.

The year 2011 has brought a rich scientific harvest on topics ranging from the structure of the universe to stars and exoplanets.

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

Furthermore, we had another very successful year of the Herschel mission with the perfect operation of the Pacs instrument.

On December 16, we celebrated in the presence of Peter Gruss (President of the Max Planck Society), Klaus Tschira (the building's sponsor), Theresia Bauer (Minister for Science, Research and the Arts, State of Baden-Württemberg), Gabriele Warminski-Leitheußer (Minister for Education, Youths and Sports, State of Baden-Württemberg), Bernhard Eitel (Rector of Heidelberg University), and Eckart Würzner (Lord Mayor of the City of Heidelberg) the inauguration of the “Haus der Astronomie”, the new education and public outreach facility on the MPIA campus at 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, November 2012

I. General

I.1 Scientific Goals

Scientific Research at the Max Planck Institute for Astronomy (MPIA, see Fig. I.1.1) 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 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 groundbased and space-based instrumentation.

The research at the MPIA is organized within two scientific departments: Planet and Star Formation and Galaxies and Cosmology.

In addition to the staff in these departments, the Institute had in 2011 five independent Junior Research Groups (two Emmy Noether groups supported by the German Science Foundation DFG, and three groups supported by the Max Planck Society).

Over the course of the year 2011, there were a total of about 60 postdoctoral stipend holders, about 90 PhD students, and 13 diploma and master's students and student assistants working at the institute.

Strong ties exist between MPIA and the University of Heidelberg, with its Center for Astronomy (ZAH), both in research and teaching, 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 gal-

Credit: MPIA / AMQ

Fig. I.1.1: The main building of the MPIA on the Königstuhl.

axies 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 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 PanStarrs-1 survey which has successfully started in 2010; the Sloan Digital Sky Survey (SDSS) and Segue for the Milky Way and Local Group; complemented since 2008 by the LBC cameras at 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.

Fig. I.1.2: The galaxy GC 4651 with its remarkable umbrella-like structure. It is composed of tidal star streams, the remnants of a smaller satellite galaxy.

Credit: R. Jay Gabany, D. Martínez-Delgado

Credit: ESA / HUBBLE, NASA and D. A. Gouliermis (MPIA)

Fig. I.1.3: Star Formation in LH 72, a cluster located at the northern periphery of the super-giant shell LMC 4 in the Large Magellanic Cloud.

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 sub–millimeter observations, numerical (magneto-) hydrodynamical simulations, and radiative transfer studies. Imaging with the HUBBLE Space Telescope and the wealth of data from the SPITZER Telescope and now from HERSCHEL 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 highresolution 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 Max Planck Institute for Astronomy 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 two largest telescopes with 2.2 m and 3.5 m mirrors are still 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 which is now used for regular science programs. The year 2008 has seen the installation and the beginning of the commissioning of the first of the two Luci instruments, jointly built by the Landessternwarte of the Center for Astronomy of Heidelberg University (ZAH), the MPIA, and the MPE. Additional contributions were also made by the Ruhr University Bochum and the Fachhochschule Mannheim. Science demonstration observations with this near-infrared multi-object spectrometer have commenced in December 2009 and 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 in 2010 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.

Fig. I.2.1: Areal View of the Calar Alto Observatory (Caha).

Credit: CAHA

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.
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 chapter III.1 of our annual report for 2010) have been published in a dedicated Astronomy & Astrophysics special issue. And thanks to a trouble-free operation, Herschel provided us also in 2011 with excellent data.

The new generation of instruments for 8 m-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, 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 near-infrared multi-object spectrograph Luci-1

Fig. I.2.2: The Very Large Telescope at Cerro Paranal, in the Northern Chilean Andes.

Credit: J. L. Dauvergne, G. Hüdepohl / Eso 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 (see chapter IV.1), which grants full access rights to the data from a 1.8 m wide-field telescope on Haleakala/Maui (Hawaii) with a new 1.4 Gigapixel camera – the largest digital camera ever built. Since 2010, PS1 provided MPIA scientists with regular survey data.

These collaborations enable MPIA astronomers to observe the northern and the southern sky with first class 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 (ELTs).

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 the 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 with 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. 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 $0\overset{\prime}{.}5 \times 0\overset{\prime}{.}5$. 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 by far 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 $10\overset{\prime\prime}{.}5 \times 10\overset{\prime\prime}{.}5$ 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

Credit: John Hill, LBTO

Fig. I.2.3: The building of the Large Binocular Telescope (LBT) on Mt. Graham, Arizona.

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 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 $4\,\mathrm{K} \times 4\,\mathrm{K}$ 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 2010, an Eso commission led by MPIA already finished the search for the site of the planned 39 m E-ELT. 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).

In preparation for the future with this awesome telescope, MPIA has participated in two studies for instruments: 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.

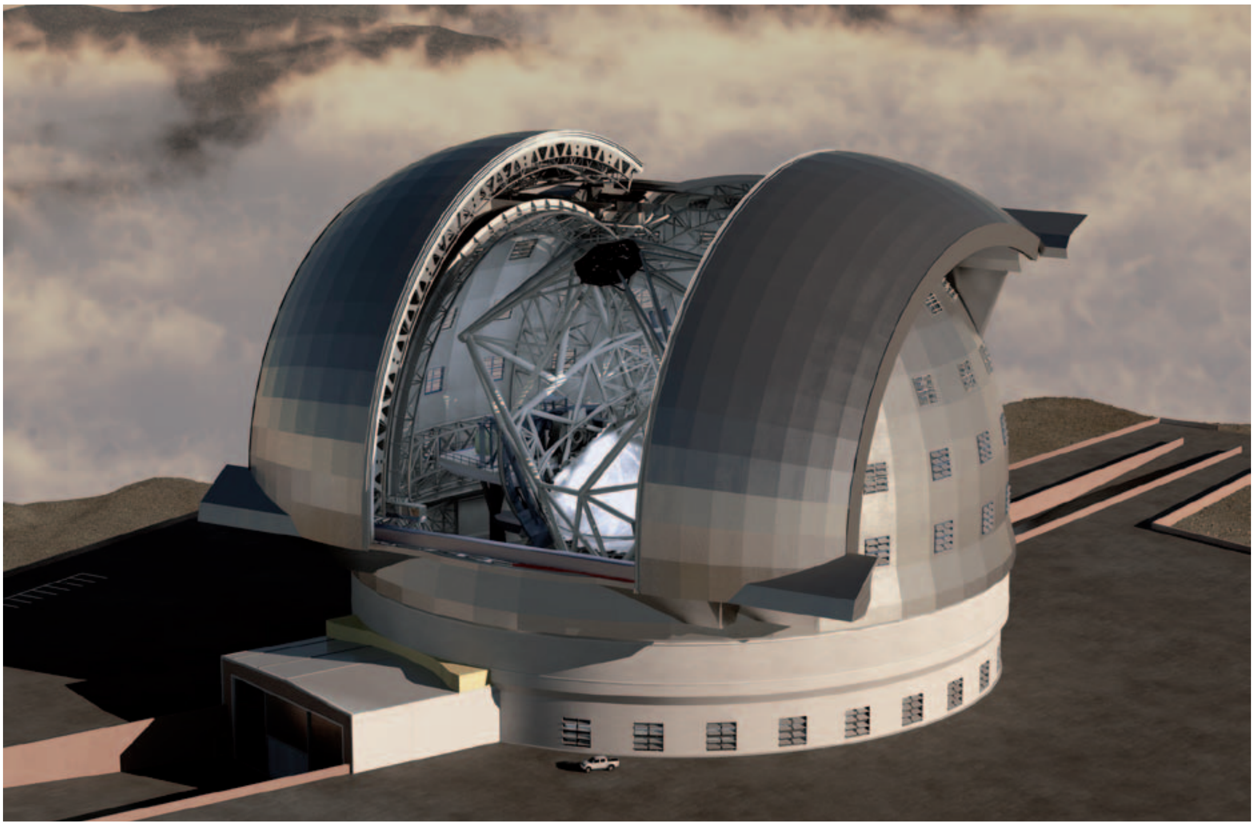
In December 2008, several concepts of the Micado study were evaluated and down-selected for a phase A study. Micado is a near-infrared imaging camera with multi-conjugated adaptive optics that will provide a spatial resolution exceeding that of the James Webb Space Telescope (JWST) by a factor of 6 to 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 $z < 1$.

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 14th May 2009. The MPIA has been one of the major partners in the development of the Pacs instrument which enables 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.

Fig. I.2.4: The European Extremely Large Telescope, E-ELT.



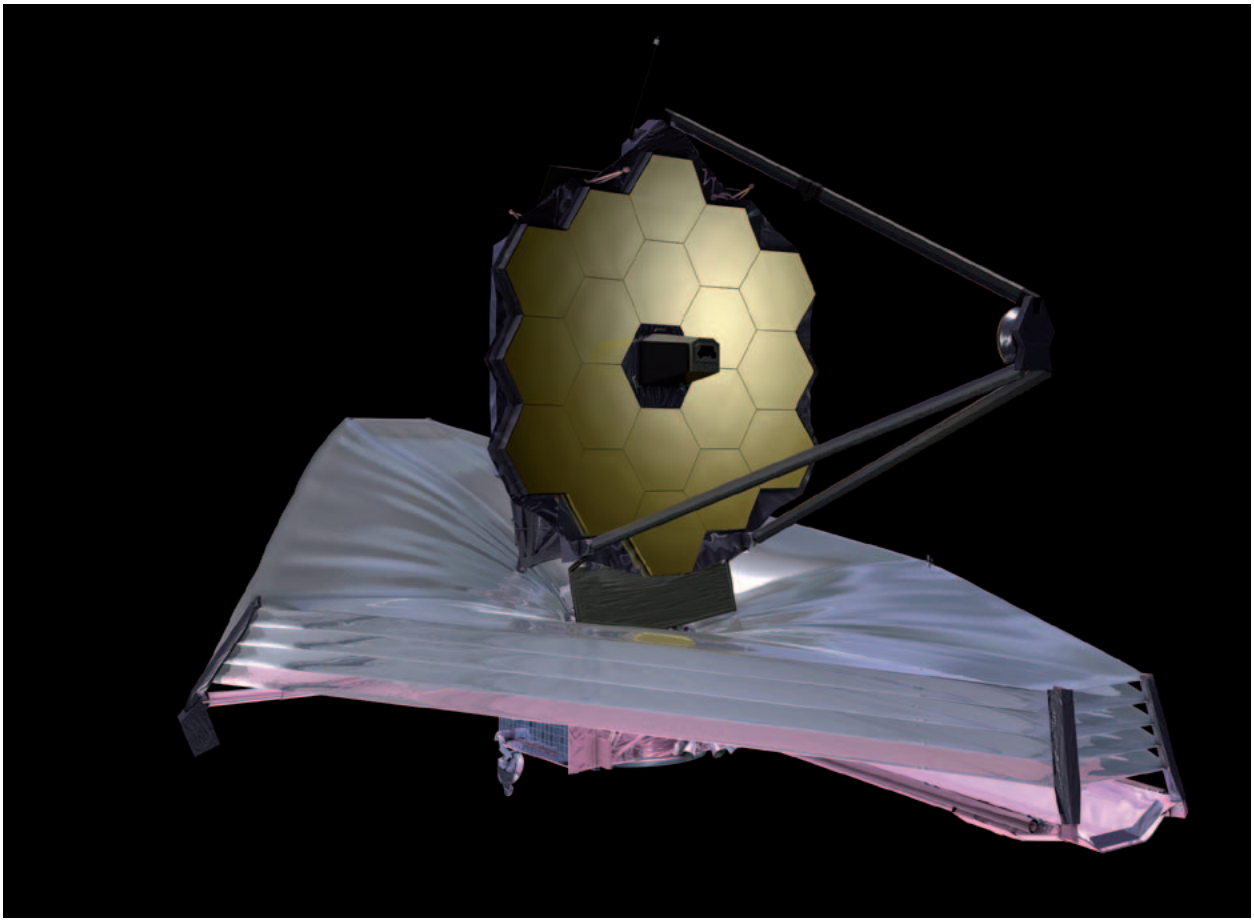
Credit: ESO/L. Calçada

Credit: Esa / Aoes Medialab

Fig. I.2.5: The Herschel Space Observatory.

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 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 set-up of the Ge:Ga spectrometer detector arrays following a procedure developed in the MPIA space laboratory (see

Fig. I.2.6: Design model of the James Webb Space Telescope (JWST), with its large segmented primary mirror and characteristic sun shield.



Credit: Nasa

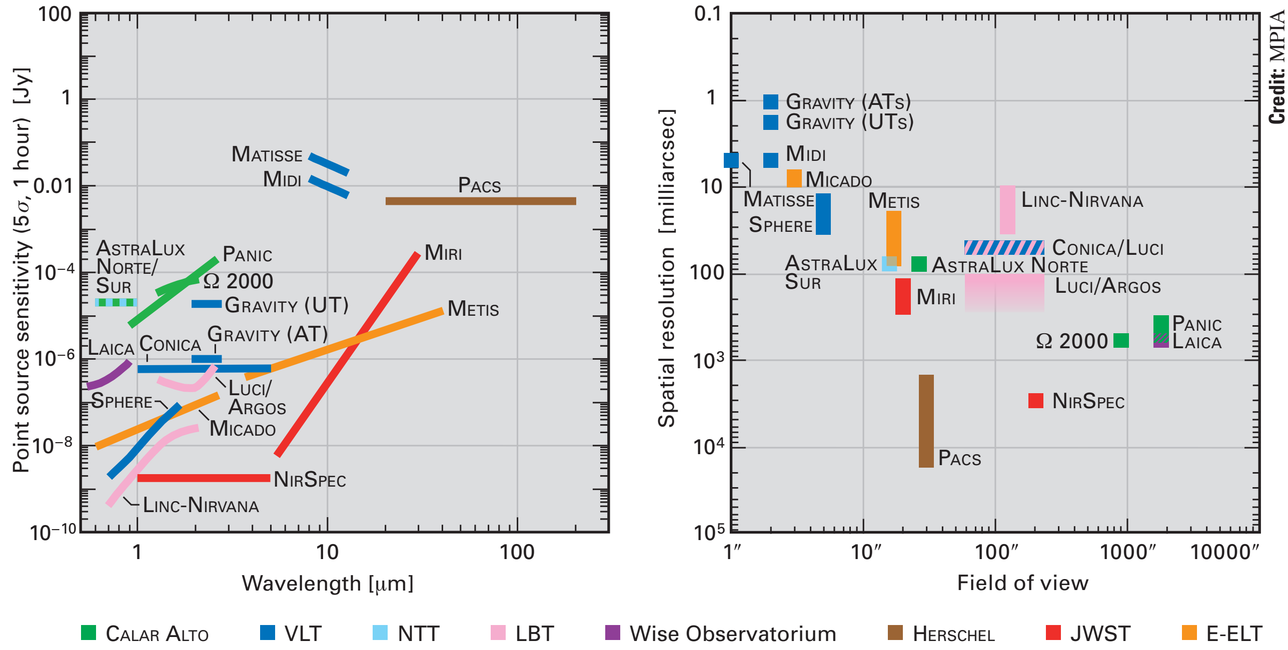


Fig. 1.2.7: Capabilities of MPIA's major instruments. *Left:* sensitivity as a function of wavelength. *Right:* spatial resolution as a function of field of view.

chapter III.1 of the annual report 2010 for details about Herschel and some of the excellent scientific data obtained in the first year of the regular mission).

The MPIA is the leading institute in Germany for the development of instrumentation for the James Webb Space Telescope (JWST, Fig. I.2.6), 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 has closely co- operated 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 Institute 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 gala-xies, 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 $z \sim 2$, 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 square degrees 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. During October 2011, Euclid was selected as one of two missions to be carried out. A possible launch date could be 2017 or 2018.

EChO is another Esa Cosmic Vision mission and will be the first dedicated mission to investigate the atmospheres of exoplanets. EChO will provide simultaneous multi-wavelength spectroscopic observations at medium resolution and with very long exposure times. The observatory will analyse the structure of the atmospheres, the abundances of the major molecules (oxygen and carbon) or magnetospheric signatures. For this purpose, EChO will focus on transiting expoplanets to benefit, e.g., from the star's light passing through the limb of the planet's atmosphere. Regarding the scientific and the technical background, MPIA made important contributions for the mission proposal. In the technical preparation the Institute has worked closely together with Astrium (Friedrichshafen/Ottobrunn) and was financially supported by DLR. Currently, the feasibility study (Phase 0/A) for EChO is carried out and MPIA is leading an European consortium to study the scientific Instrument of the mission – funded by DLR and supported by the companies Astrium, Kayser-Threde and AIM.

Finally, Spica, the Space Infrared Telescope for Cosmology and Astrophysics, is another 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 after Herschel observing in the far infrared and to be launched probably in 2017. It will feature a cold 3.5 m telescope providing up two orders of magnitude sensitivity advantage, mostly for spectroscopic observations, over existing far-infrared facilities. 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. Currently, the European contribution to the observatory is in an extended assessment phase, keeping it in line with the status of the project at Jaxa.

Fig. I.2.7 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

The 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 for Nuclear Physics (MPIK), 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, MPIA has extensive cooperations with the MPI for Extraterrestrial Physics in Garching and the MPI for Radio Astronomy in Bonn, as well as with numerous other German institutes, whose locations are shown in Fig. I.3.1.

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

Fig. I.3.1: Position of the partner institutes of the MPIA in Germany.

Credit: Mountain High Maps / MPIA graphic made by German institutes in this field and to accomodate 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 and Gravity.

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 Leibniz Institute for Astrophysics in Potsdam (AIP), the Astrophysical Institute of Jena University, the Kiepenheuer Institute for Solar Physics in Freiburg, the MPI for Extraterrestrial Physics in Garching, the MPI for Radio Astronomy in Bonn, the University of Hamburg, the I. Physical Institute of Cologne University, and the Universities of Kiel and Munich.

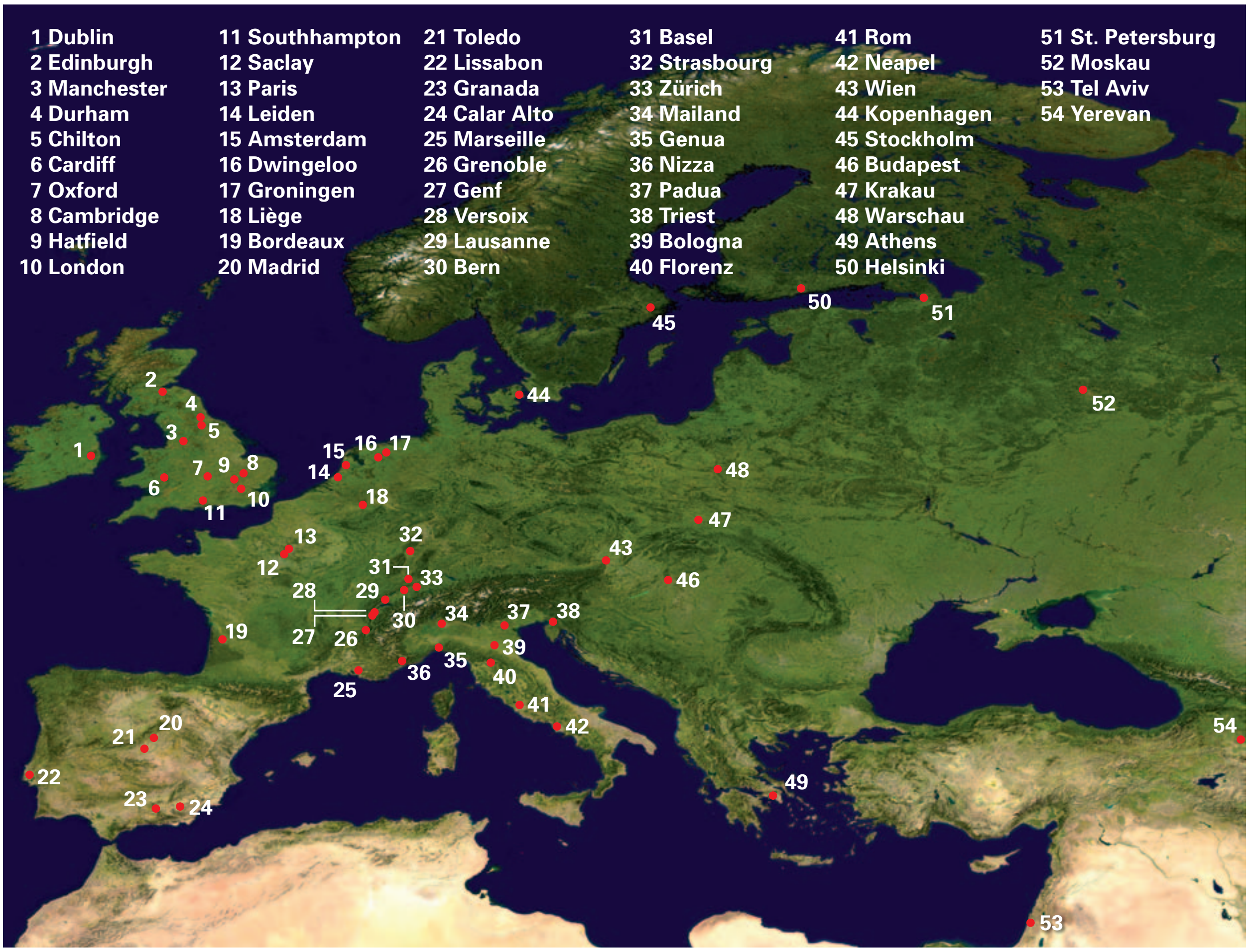
The MPIA is participating in a number of EU- networks and worldwide collaborations, in part as project leader. These include:

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.

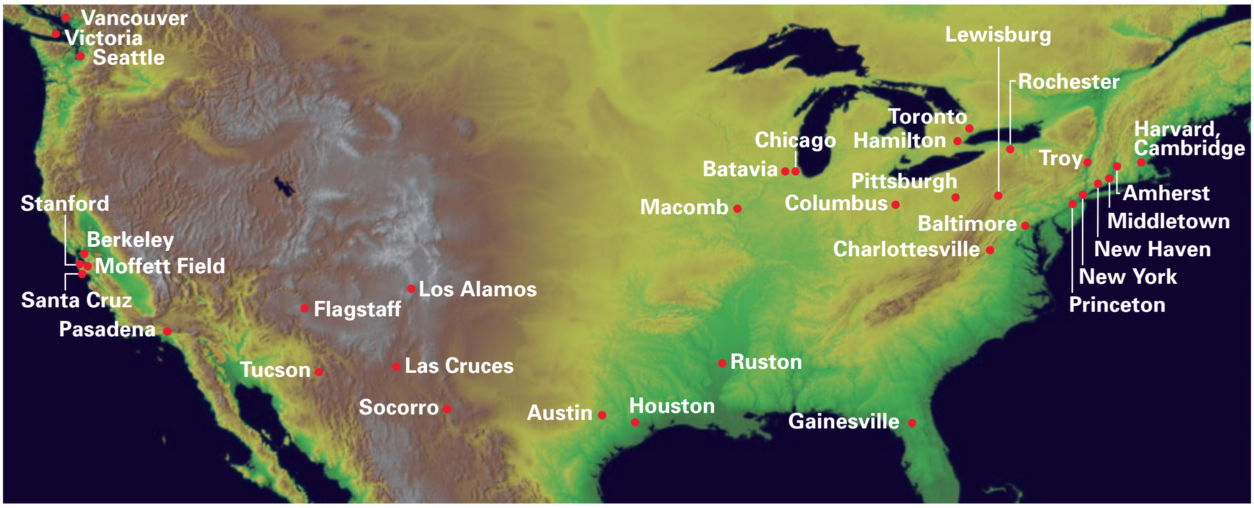
Espri (Exoplanet Search with Prima): This project aims at carrying out the first systematic astrometric planet search with a measurement accuracy of 10–20 micro-arcseconds. For this purpose, we have built, in collaboration with Eso, the Landessternwarte Heidelberg, and the Geneva Observatory in Switzerland, 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 (T-Tauri) and intermediate-mass (Herbig Ae) stars. For that, we employ multimolecule, multi-line observations with the Plateau de Bure interferometer and the IRAM 30 m an-

Fig. I.3.2: Position of MPIA's international partner institutes. See also on the following page.



Credit: Nasa "Blue Marble" / MPIA graphic



Credit for both figures: NASA "Blue Marble" / MPIA graphic

tenna, 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. The project is currently within it´s 2nd funding period (from January 2010 until December 2012).

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 provides 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 completed, and an extension, SDSS-II/Segue,, focusing on Milky Way structure, was completed in mid 2008.

MPIA is a partner in Pan-Starrs1 (PS1) see also chapter IV.1, 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 operates the PS1 telescope during 2009 – 2012 to carry out multiple time-domain imaging surveys in its g, r, i, z, y filter set: the "3pi" 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 institute 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 Herschel guaranteed 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 and 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" (HdA), a new center for education and public outreach, whose establishment had been decided in December 2008, has been finally erected on the Campus of the MPIA during 2011. 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 are an excellent 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. After a successful evaluation in 2009, the IMPRS-HD was extended for another period

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

Fig. I.4.1: The HdA was finished in autumn 2011. The main entrance is to the right.

Credit: MPIA

its sixth year in 2011, 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 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 2011, 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 the 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

In December 2011, the "Haus der Astronomie", which was founded in December 2008, has been finally 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 has financed 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, and the University of Heidelberg are contributing to the personnel costs, and the astro-nomers 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 2009 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 2010. And only one year later, on December 16 2011, we celebrated in the presence of Peter Gruss (President of the Max Planck Society), Klaus Tschira (the building's sponsor), Theresia Bauer (Minister for Science, Research and the Arts, State of Baden-Württemberg), Gabriele Warminski-Leitheußer (Minister for Education, Youths and Sports, State of Baden-Württemberg), Bernhard Eitel (Rector of Heidelberg University), and Eckart Würzner (Lord Mayor of the City of Heidelberg) the inauguration of the "Haus der Astronomie" (see chapter V for more details about the HdA).

II. Highlights

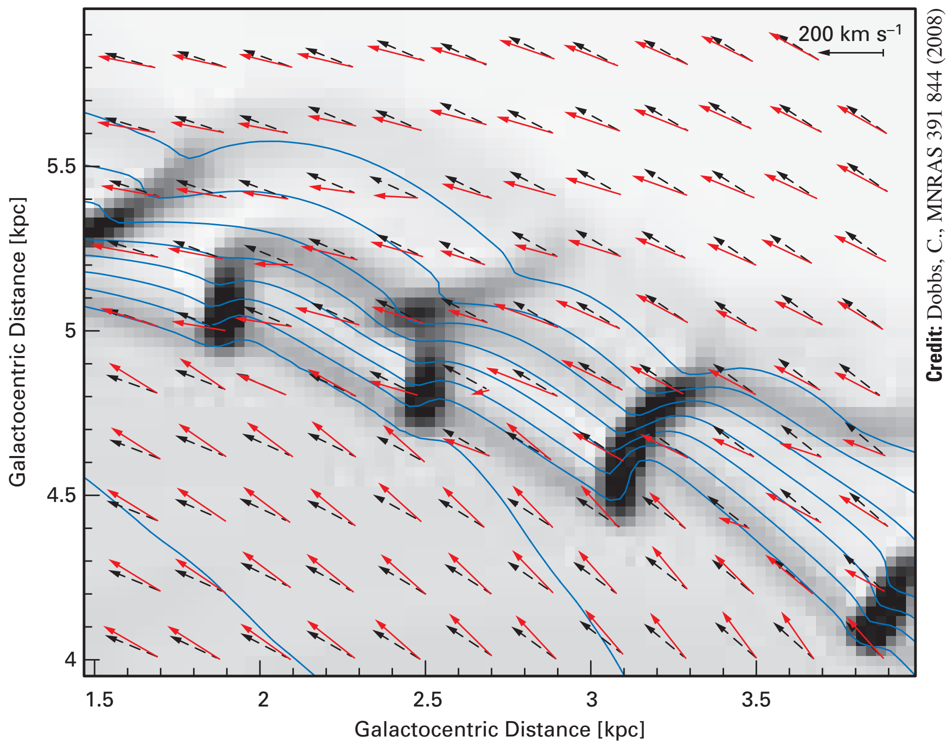
II.1 Anchoring Galactic Magnetic Fields in Giant Molecular Clouds: A Bird's-eye View

Magnetic fields set the stage for the birth of new stars

Astronomers at MPIA have measured for the first time the alignment of magnetic fields in gigantic clouds of gas and dust in a distant galaxy. The results suggest that such magnetic fields play a key role in channelling matter to form denser clouds, and thus in setting the stage for the birth of new stars. The work was published in the November 24 edition 2011 of the journal Nature.

The relationship between galaxy-wide magnetic fields (B-fields) and localized molecular clouds is not well understood. Some models of cloud formation suggest that the large scale galactic field is largely irrelevant at the small scale of individual clouds, because turbulence and rotation of a cloud might randomize the cloud field orientations (see Dobbs, C., MNRAS 391 844 (2008) and Fig. II.1.1 bottom). Others suggest that the galactic B-fields can be strong enough to impose their directions upon the clouds (See Fig. II.1.1 top and Shetty, R. & Ostriker, E. ApJ 647, 997 (2006)).

The implication for star formation is that the ordered cloud B-fields in the latter scenario can regulate cloud fragmentation and affect star formation rate and efficien-



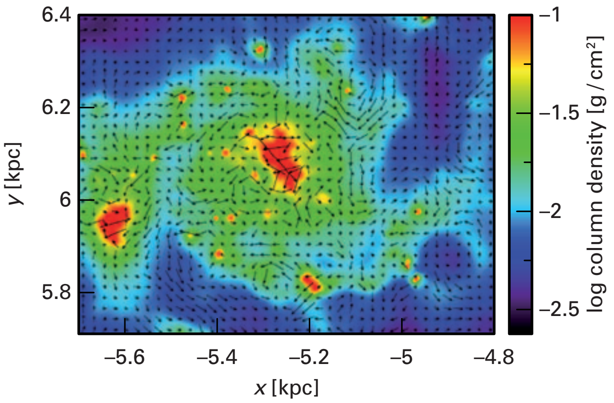


Fig. II.1.1: Two competing scenarios of cloud formation. *Top:* A patch from a global galaxy simulation. The solid vectors show the instantaneous gas velocity in the frame rotating with the spiral potential. The dotted vectors show the initial velocities (pure circular motion). The solid lines show B-field orientations. The gray scale stands for the relative surface density. The B-fields of the spiral arm are only slightly twisted in the molecular cloud complexes (dark elongated regions), and in turn the field tension is strong enough to hinder the cloud rotation. *Bottom:* A similar simulation but the well developed cloud rotation has produced tidal tails extending from the GMC, and the B-fields (vectors) follow the rotation and lost the "memory" of the galactic field direction.

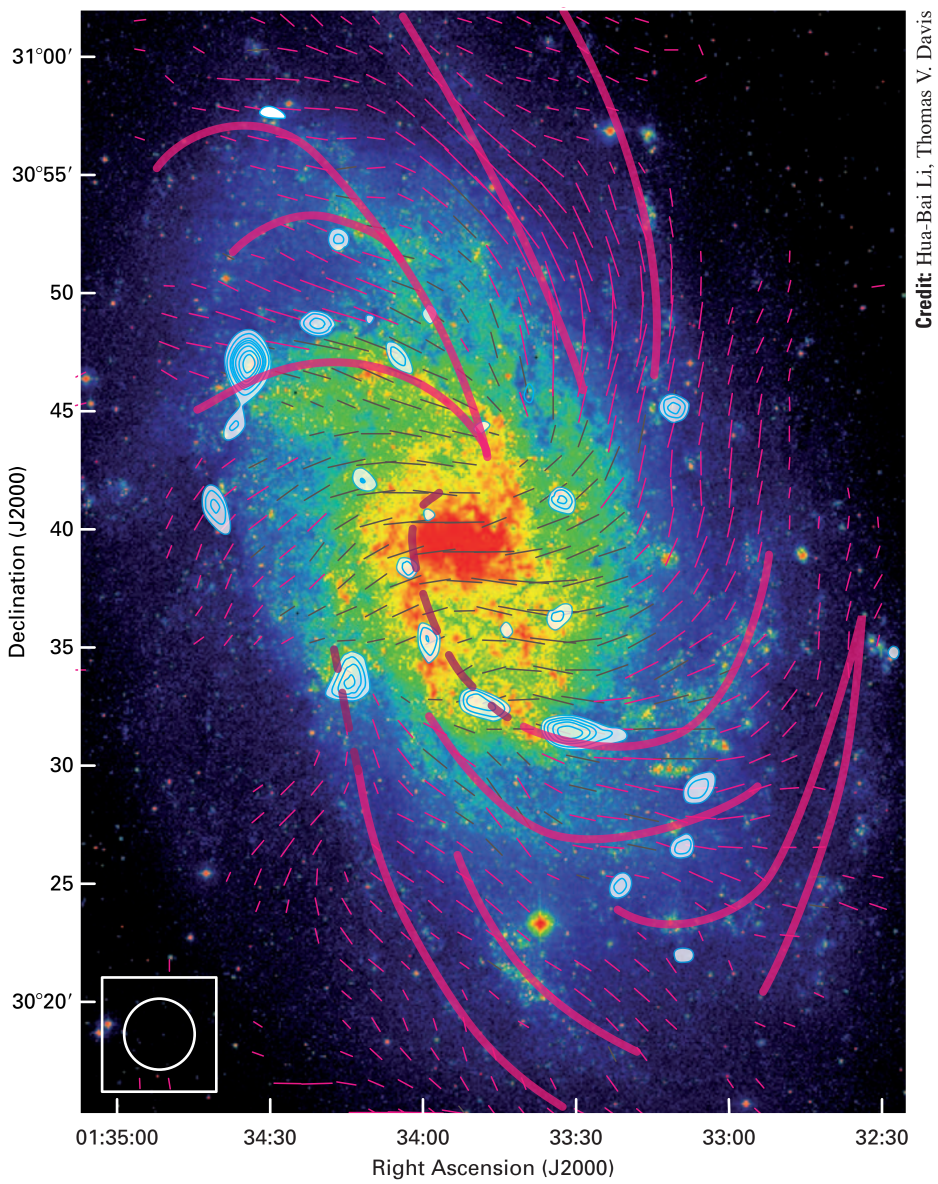


Fig. II.1.2.: Locations of the 6 most massive GMCs ("+"s) and the optical spiral arms in M33. The background is an optical image of M33 from Thomas V. Davis. The white lines trace the optical arms adopted from Sandage, A. & Humphreys, R. ApJ 236, 1 (1980) and Rogstad, D., Wright, M. & Lockhart ApJ 204, 703 (1976).

cy. This is because, just like the Earth B-field can channel the Solar wind toward the polar regions (and form aurora), strong B-fields can channel the gravitational contraction of gas and form molecular clouds. Cloud fields inherited from the galaxy are possible to further channel the gas motion within the cloud and preserve the direction of the galactic B-field.

A measurement of the field direction in individual clouds and comparison to the spiral arms should determine which model is correct, but is difficult in the Milky Way because the arms cannot be observed due to the edge-on view of the Galactic disk.

The efficiencies of the state of the art instruments are not sufficient to probe the cloud B-fields from a face-on galaxy with the conventional B-field tracers. Here we report a novel strategy to tackle extragalactic cloud B-fields. We determine B-field directions using the polarization of CO emission lines, which should be either perpendicular or parallel to the local B-field direction projected on the sky (the Goldreich-Kylafis-effect, see Goldreich, P. & Kylafis, N., ApJ 243, 75 (1981) for details).

Though there are other B-field tracers that do not have this 90° ambiguity, CO is much more abundant and allows current radio telescopes to perform extragalactic cloud observations. Our argument for using the Goldreich-Kylafis-effect is that the 90° ambiguity can still be statistically useful. An intrinsically random field distribution, as happens when the turbulence is super-Alfvenic (i.e., turbulent energy dominates B-field energy), will still be random with this ambiguity. On the

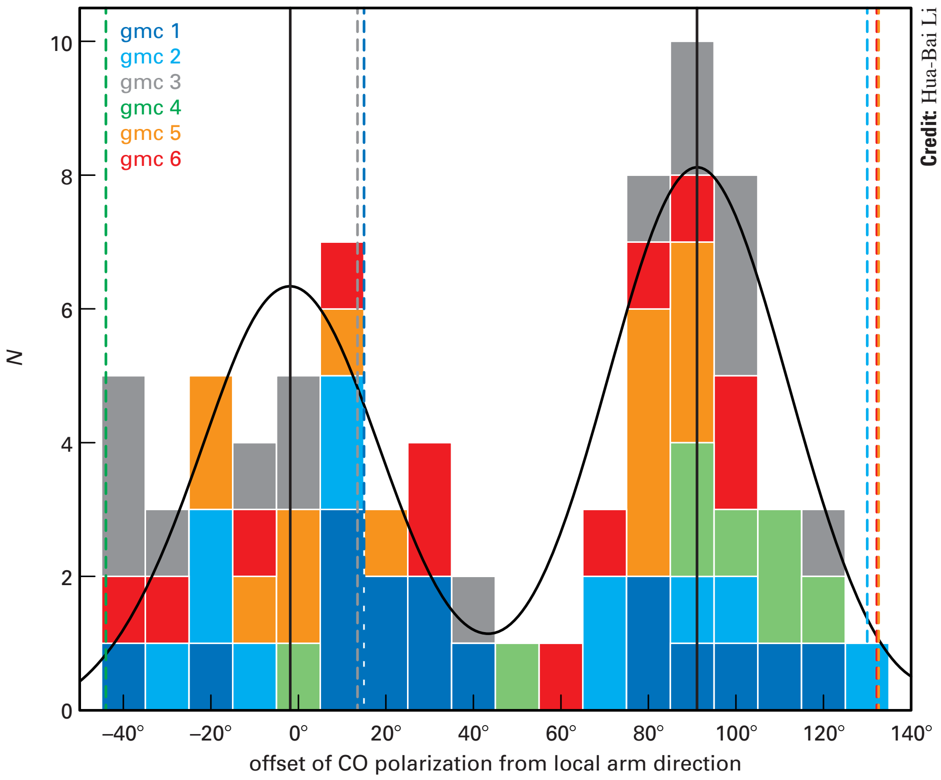


Fig. II.1.3.: Distribution of the polarization-arm offsets. The offsets are from the difference between the orientations of CO polarization and local arms. Contributions from different GMCs are distinguished by the colors. The distribution can be fitted by a double-Gaussian function with a standard deviation of 20.7° ± 2.6° and peaks at –1.9° ± 4.7° and 91.1° ± 3.7°, suggesting that the cloud B-field directions are correlated with the arm directions. The directions of synchrotron polarization, which traces the B-field from the low-density warm vicinities of each cloud, are also shown as the dashed lines. The fields in the less compressed warm media do not align with the spiral arms.

other hand, an intrinsically single-peaked Gaussian-like field distribution, as happens when the turbulence is sub-Alfvenic, will either stay single-peaked, or split into two peaks approximately 90° apart.

M 33 is the nearest face-on galaxy with pronounced optical spiral arms. We used the Submillimeter Array at Mauna Kea (SMA), which offers a linear spatial resolution of ~15 parsecs at 230 GHz (the frequency of the CO J = 2–1 transition) at the distance of M 33 (900 kpc). (The Goldreich-Kylafis effect has been detected by the SMA before from a Galactic cloud, see Beuther (also MPIA) et al. in ApJ 724, 113, 2010).

We picked the six most massive clouds (Fig. II.1.2) from the BIMA M 33 survey because of their strong CO line emission. The distribution of the offsets between the CO polarization and the local arm directions clearly show the trend of "double peaks" (Fig. II.1.3).

The distribution can be fitted by a double-Gaussian function with the two peaks lie at –1.9° ± 4.7° and 91.1° ± 3.7° and a standard deviation of 20.7° ± 2.6°. This indicates that the mean field directions are well-defined and highly correlated with the spiral arms, consistent with the scenario that galactic B-fields can exert tension forces strong enough to resist cloud rotation (Fig. II.1.1 top).

The ~20° dispersion of the field direction is also important, which implies that the cloud turbulence is sub-Alfvenic, based on the Chandrasekhar-Fermi criterion. Whether molecular clouds are sub- or super-Alfvenic is another long-lasting debate and is a critical assumption made in various theories of star formation.

Hua-Bai Li and Thomas Henning

II.2 Subaru observations of solar systems in the making

Using the Subaru Telescope in Hawaii, a team of astronomers including MPIA scientists have shown the protoplanetary disks surrounding two young stars in unprecedented detail. This is the first time that disk structures comparable in size to our own solar system have been resolved this clearly, revealing features such as rings and gaps that are associated with the formation of giant planets. The observations are part of the Seeds project in which MPIA is involved: a systematic survey to search for planets and disks around young stars using HiCIAO, a state-of-the-art high-contrast camera designed specifically for this purpose.

Planetary systems like our own share a humble origin as mere by-products of star formation. A newborn star's gravity gathers leftover gas and dust in a dense, flattened disk of matter orbiting the star. Clumps in the disk sweep up more and more material, until their own gravity becomes sufficiently strong to compress them into the dense bodies we know as planets. As documented in MPIA annual reports, among other places, recent years have seen substantial advances both in observations (mostly indirect) and in theoretical modeling of such protoplanetary disks. The two recent observations described in this highlight have added intriguing new details, revealing some structures that had never before been seen directly.

The lopsided disk of LkCa 15

One of the two studies, led by Christian Thalmann while on staff at MPIA, targeted the star LkCa 15, which is located around 450 light-years from Earth in the constellation Taurus. At an age of a few million years, LkCa 15 is a young star – the Sun, after all, is a thousand times older. From previous observations of its infrared spectrum and its millimeter emissions, scientists had deduced the presence of a large gap in the center of the star's protoplanetary disk.

The new images were taken with the HiCIAO camera in the near-infrared (H band, that is, around a wavelength of 1.6 μm). The image processing used angular differential imaging (ADI). This technique exploits the fact that the field the telescope observes and the telescope's pupil

Fig. II.2.1: Image taken with the HiCIAO planet-hunter camera on the Subaru Telescope, which shows a bright arc of scattered light (*white*) from the protoplanetary disk around the young star LkCa 15 (*center, masked out with a dark circle*). The arc's sharp inner edge traces the outline of a wide gap in the disk. The gap is decidedly lopsided – it is markedly wider on the left side – and has most likely been carved out of the disk by one or more newborn planets that orbit the star.

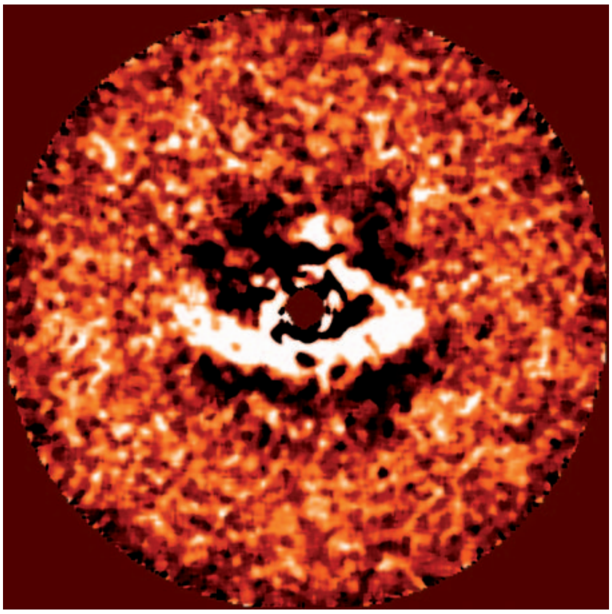
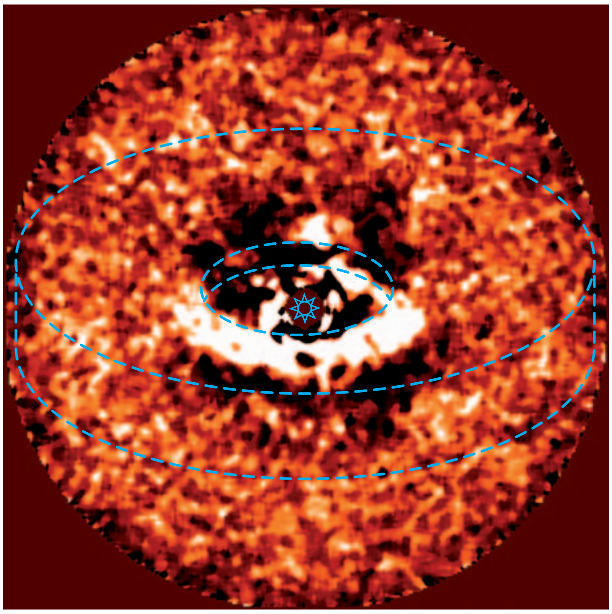


Fig. II.2.2: A reconstruction of the geometry of the disk around LkCa 15 (*dashed blue lines*) superimposed on the HiCIAO image. The bright arc represents light from the central star (LkCa 15) that reflects off the surface of the disk. This kind of light scattering is particularly effective at grazing angles, which is why most of the observed light comes from the near side of the disk.



Credit: MPIA (C. Thalmann) & NAOJ

rotate with respect to each other during the observation. By comparing different images taken during an observing run, this information can be used to distinguish the star's halo – stray light due to the star's extreme brightness and its interaction with the telescope – from real on-sky sources as, for example, a disk surrounding a star.

The images show starlight gleaming off the disk surface, clearly outlining the sharp edge of the gap for the first time. Most interestingly, the elliptical shape of the gap is not centered on the star, but appears lopsided.

The most likely explanation for LkCa 15's disk gap, and in particular its asymmetry, is that one or more planets, freshly born from the disk material, have swept up the gas and dust along their orbits. Intriguingly, the disk gap is sufficiently large to accommodate the orbits of all the planets in our own Solar System. It is therefore tempting to speculate that LkCa 15 might be in the process of forming an entire planetary system much like our own. Further observation could soon detect those planets.

A detailed view of AB Aurigae

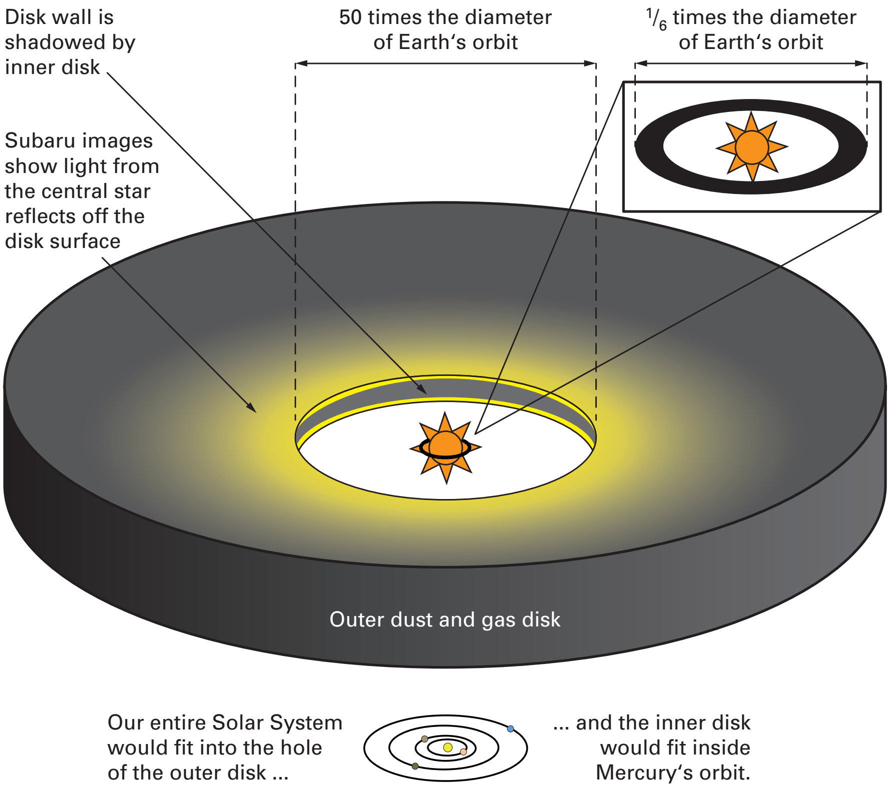
The second observation, led by Jun Hashimoto (National Observatory of Japan), targeted the Herbig AE star AB Aur in the constellation Auriga, at a distance of 470 light-years from Earth. This star is even younger, with an age of a mere one million years.

The observations, polarized intensity images at a near-infrared wavelength of 1.6 µm, were the first to show details down to length scales comparable to the size of our own solar system – for comparison: At a distance of 470 light-years, the solar system has the same apparent size as a 1 Euro coin viewed at a distance of more than 10 km. The disk has a radial distance from its mother star between 22 and 554 the mean Earth-Sun distance (22–554 AU). The observations show nested rings of material that are tilted with respect to the disk's equatorial plane, and whose material, intriguingly, is not distributed symmetrically around the star – irregular features including a bumpy double ring and a ring-like gap, that indicate the presence of at least one very massive planet.

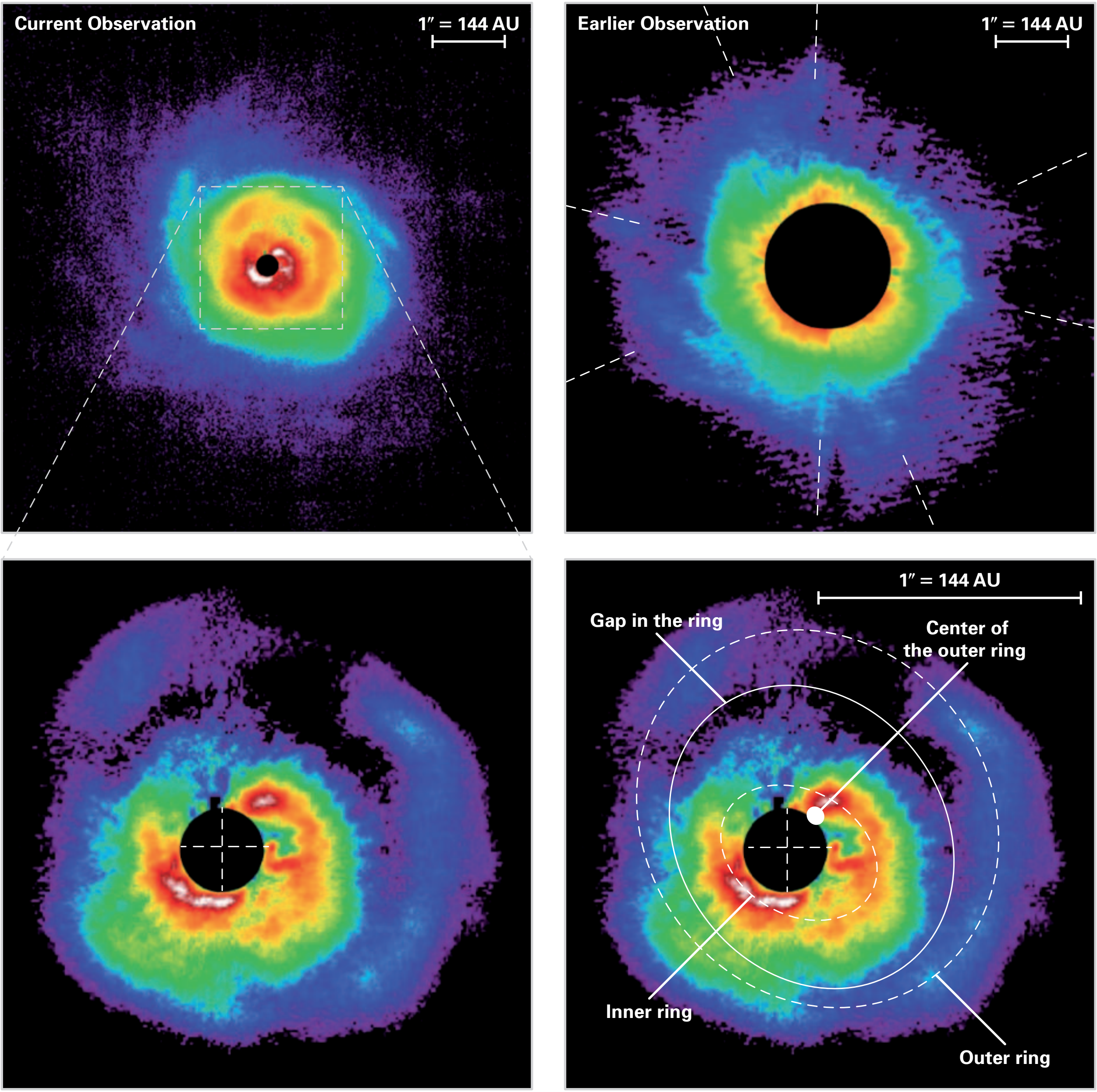
HiCIAO and the Seeds project

Both observations where made with the HiCIAO instrument at the 8.2 m Subaru Telescope located at Mauna Kea at Hawaii. Imaging a disk or planet close to a star is an enormous challenge, as it is very difficult to discern the light emitted by those objects in the star's intense glare. HiCIAO meets this challenge by correcting for the distorting influence of the Earth's atmosphere using

Fig. II.2.3: Sketch of the three-dimensional shape of the protoplanetary disk around the star LkCa 15. Only the light reflected from the outer disk (*shown in yellow*) is seen on the HiCIAO images. The other structural features have been inferred from previous indirect observations of the system. The large gap between the inner and the outer disk has most likely been carved out by one or more newborn planets that orbit the star. The planets themselves have not been detected – yet.



Credit: MPIA (C. Thalmann) & NAOJ



Credit: NAOJ/J. Hashimoto

Fig. II.2.4: Recent near-infrared images of AB Aur taken by HiCIAO (*top left*), compared with an image taken in 2004 by its predecessor instrument CIAO (*top right*). The new images give a much more detailed view of the inner regions (*bottom left; with explanations bottom right*): Intricate bright and dark patterns indicate the presence of different rings of matter. The fact that their centers do not coincide with the position of the star and the other irregularities point to the existence of a massive giant planet which is sweeping up the material between the rings.

Adaptive Optics, and by physically blocking out most of the star's light using a coronagraph.

The observations are part of the SEEDS project, short for "Strategic Explorations of Exoplanets and Disks with SUBARU": a five-year systematic search for exoplanets and protoplanetary disks using observations such as the ones described here, which are widely regarded as a key to understanding the formation of protoplanetary systems. SEEDS involves more than 100 researchers from 25 astronomical institutions in Asia (NAOJ and others), Europe (MPIA and others), and the US (Princeton University and others).

The scientific publications regarding the observations presented here are: C. Thalmann, et al. 2010, »Imaging of a Transitional Disk Gap in Reflected Light: Indications of Planet Formation Around the Young Solar Analog LkCa 15« in Astrophysical Journal Letters 718, p. L87-L91, and J. Hashimoto, et al. 2011, "Direct Imaging of Fine Structures in Giant Planet-forming Regions of the Protoplanetary Disk Around AB Aurigae" in Astrophysical Journal Letters 729, p. L17.

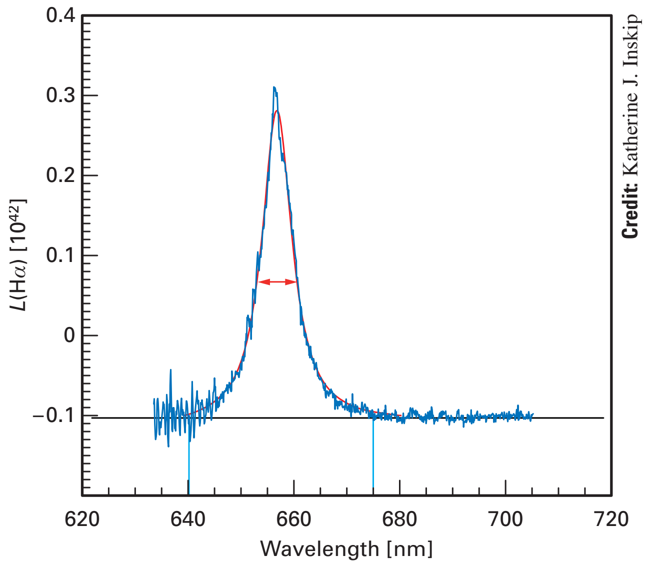
Christian Thalmann, Miwa Goto, Thomas Henning, Wolfgang Brandner, Joseph Carson, Markus Feldt

II.3 In what Galaxies do Black Holes live in the Early Universe?

Using state-of-the-art technology and sophisticated data analysis tools, a team from MPIA has developed a new and powerful technique to directly determine the mass of a galaxy hosting an active supermassive central black hole at a distance of nearly 9 billion light-years from Earth. This pioneering method promises a new approach for studying the co-evolution of galaxies and their central black holes, which typically relies on mass determinations.

One of the most intriguing developments in astronomy over the last few decades is the realization that not only do most galaxies contain central black holes of gigantic size, but also that the mass of these central black holes are directly related to the mass of their host galaxies. These scaling relations with the black hole mass have been found to exist with the galaxy's stellar or dynamical bulge mass, total luminosity and stellar velocity dispersion. It has recently been realized that these correlations are expected as a consequence of the current standard model of galaxy evolution, the so-called hierarchical model, as astronomers from MPIA have shown (Jahnke & Macciò 2011, ApJ, 734, 92). In this standard model of galaxy formation galaxies evolve and grow by ingesting smaller galaxies, or through mergers with galaxies of comparable size. As a a consequence of this hierarchical formation, the individual relations between bulge and black hole mass are averaged out, creating a nearly universal ratio between the two properties in every galaxy.

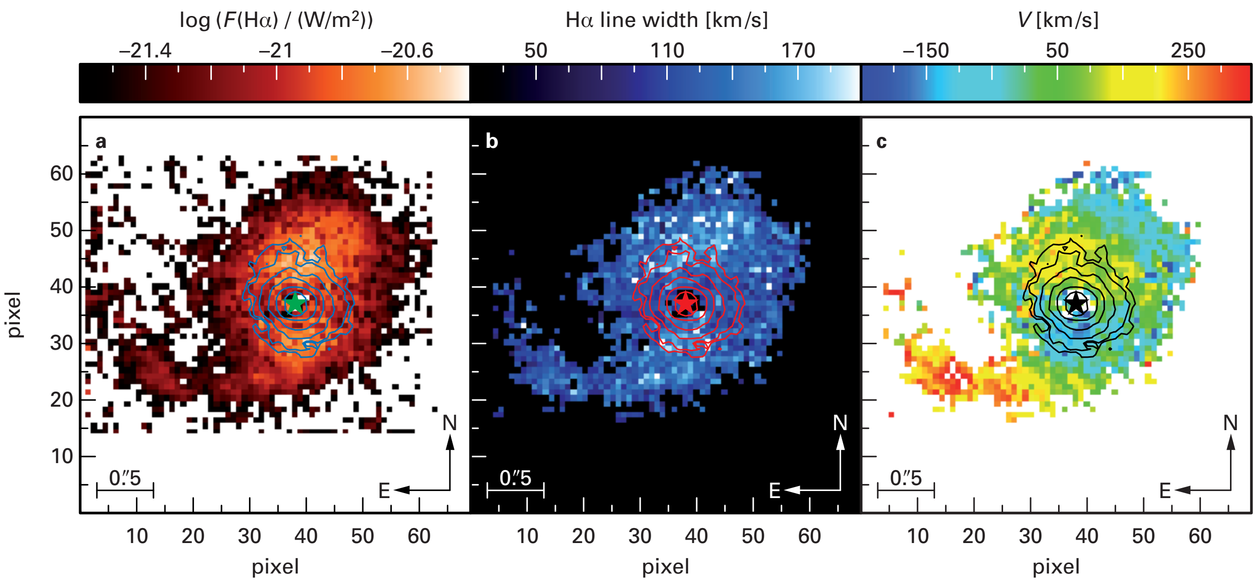
One of the most robust methods to study how galaxies and black holes evolve relative to each other is to trace these scaling relations through cosmic time. This can



Credit: Katherine J. Inskip

Fig. II.3.1: Spectrum around Hα for the quasar SDSS J090543.56+043347.3, centered on the active nucleus. From the combination of width (red arrow) and luminosity (integral above the zero level between the blue lines) of the Hα line the black hole mass can be inferred (Greene & Ho 2005, ApJ, 630, 122). The use of Hα for this purpose reduces the systematic uncertainties present in the prior estimates using the MgII line.

Fig. II.3.2: SDSS J090543.56+043347.3: (*a*) Extracted emission line flux distribution, (*b*) Hα line width and (*c*) resulting velocity field, in all cases after removal of the bright nucleus, overlaid in contours.



Credit: Katherine J. Inskip

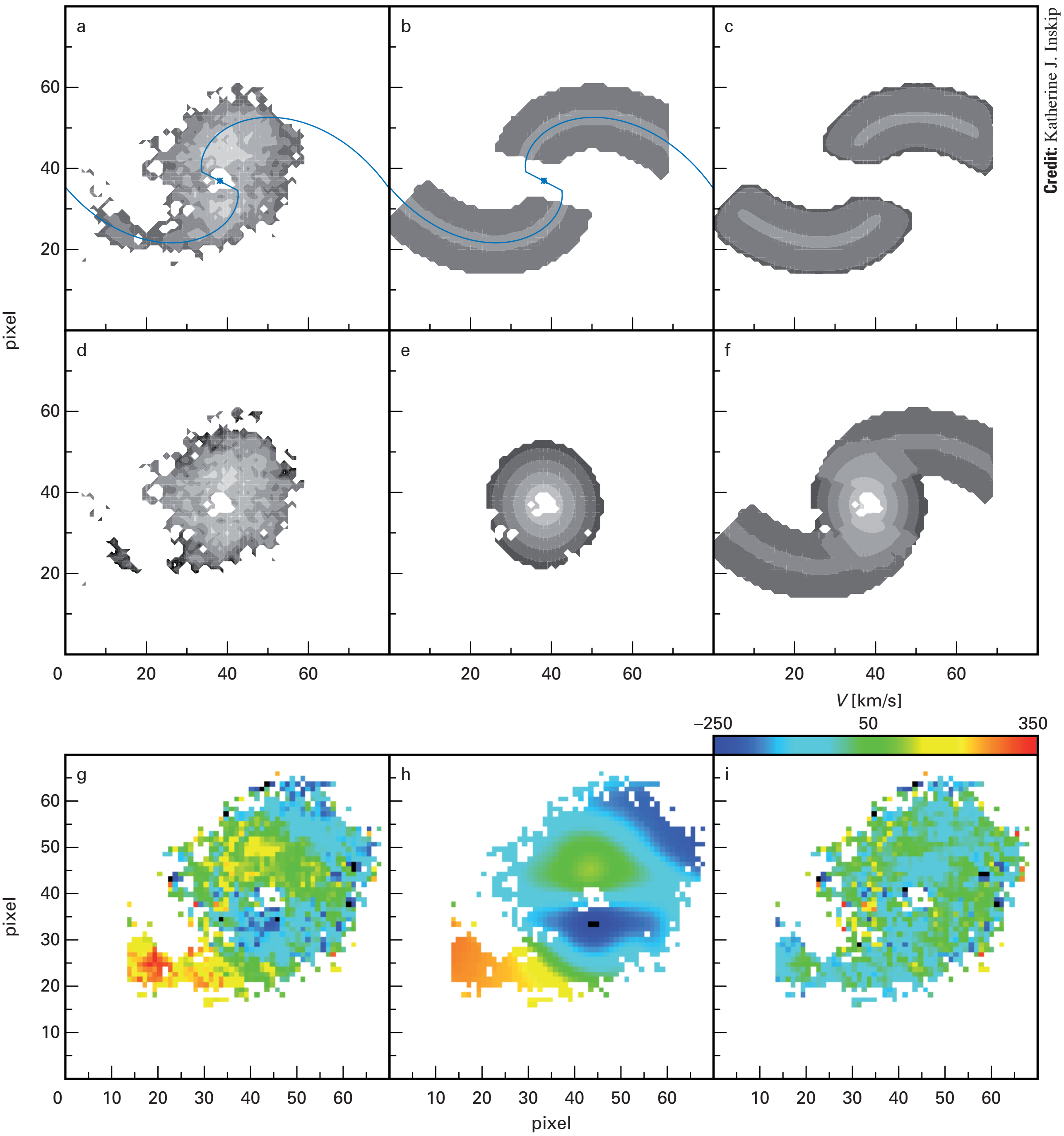


Fig. II.3.3: The extracted Hα velocity field in Fig. II.3.2c is the basis for a detailed model of the velocity structure in the galaxy. We had to separate out the peculiar motion in the galaxy associated with the arms of the galaxy, possibly created by a recent interaction with another galaxy. Flux models had to be built for the arm component (*top row a–c*) and the main galaxy (*center row d+e*) for a full flux model (*f*). This was then used to create a realistic velocity model for the main galaxy component (bottom row). (*g*) shows the measured velocity field, (*h*) the model and (*i*) the residual velocities after the model has been subtracted. There are only very small velocity residuals left. The model can be directly converted into a dynamical mass value.

be done by measuring the black-hole-mass galaxy-mass correlation at different cosmic distances, corresponding to different look-back times. We hence need to be able to determine black hole and galaxy masses at high redshifts.

For galaxies further away than 5 billion light-years (corresponding to a redshift of $z > 0.5$), such studies face considerable difficulties. The only high redshift objects for which a galaxy's central black hole mass can be measured are so called active galaxies or quasars.

These are galaxies in the special phase during which their black holes grow by swallowing surrounding matter and in the process emit enormous amounts of electromagnetic radiation. Characteristic emission lines allow the measurement of the black hole mass using a standard method which relates the width of these emission lines to the mass of the central black hole (Fig.II.3.1).

However, for these galaxies it is the galaxy's mass itself that is the challenge: At such distances, standard methods of estimating a galaxy's mass become exceedingly uncertain or fail altogether. Now we have for the first time succeeded in directly and simultaneously "weighing" both a galaxy and its central black hole at such a great distance using a sophisticated and novel method. The galaxy studied is SDSS J090543.56+043347.3, selected from the quasar sample of the Sloan Digital Sky Survey and lying at a redshift $z = 1.3$, corresponding to a distance of 8.8 billion light-years from us.

The key idea behind dynamical galaxy masses is the following: Stars and gas in a galaxy orbit its centre. The different orbital speeds of the gas clouds are a direct function of the galaxy's mass distribution. Determine orbital speeds and you can determine the galaxy's total mass. This task was very challenging. Mainly, we had to overcome two problems: For one, at such a great distance, the angular size of SDSS J090543.56+043347.3 amounts to about one arc-second – the apparent size of an ordinary DVD viewed from a distance of 25 kilometres. In order to obtain the dynamical mass of the galaxy from the motion of the galaxy's gas clouds at different regions across the galaxy had to be resolved. This was only possible using the unique combination of the SINFONI integral field spectrograph at the Very Large Telescope (VLT) belonging to the European Southern Observatory (ESO) on Cerro Paranal in northern Chile. SINFONI was coupled with an adaptive optics (AO) system with the PARSEC laser guide star which was co-developed by MPIA, to strongly reduce the atmospheric distortion of celestial images. SINFONI is able to produce a spectrum for each of 1600 pixels over a 3 × 3 arc-second field while the AO system increased the spatial resolution from about 1 arc-second to the 0.35 arc-seconds required for this project.

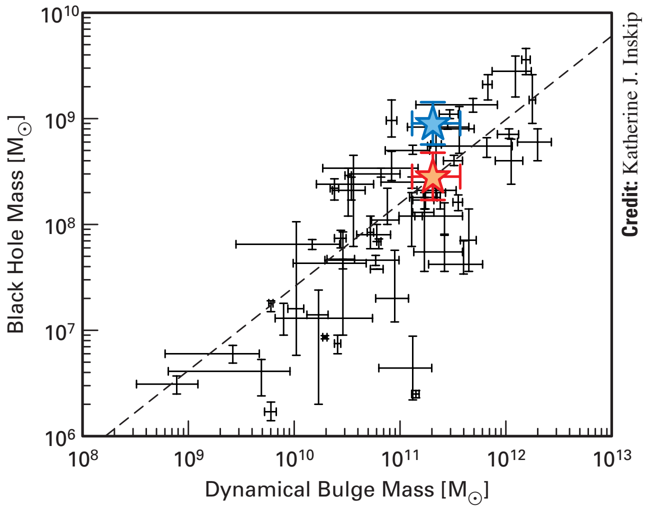
The second difficulty is the fact that SDSS J090543.56+043347.3 is a quasar, whose central region emits intense light, several times brighter than the emission from the underlying galaxy – which poses an obvious problem. For the measurement of the gas velocity field, first the extremely intense nuclear light around the black hole had to be separated from the light emitted by the moving gas clouds in the rest of the galaxy. Only after this process, the analysis and modelling of the velocity structure of the galaxy can become possible, resulting in the derived dynamical mass inside the central 5.25 ± 1.05 kiloparsecs of the galaxy of $M_{\mathrm{DYN}} = 2.05^{+1.68}_{-0.74} \times 10^{11}$ solar masses. The data and analysis involved in this are shown in Figures II.3.2 and II.3.3.

Combining this result with the mass value of the galaxy's central black hole of $M_{\mathrm{BH,H\alpha}} = 2.83^{+1.93}_{-1.13} \times 10^{8}$ solar masses, which we measured from the nuclear Hα line in the same dataset, we were able to compute the ratio of black hole to dynamical bulge mass of the galaxy. As it turns out, this value is nearly the same as that which would be expected for a present-day galaxy (Fig. II.3.4). Apparently, nothing major has changed between now and then: At least out to this distance, 9 billion years into the past, the correlation between galaxies and their black holes appears to be very close to their modern-day counterparts.

When we estimate the expected star formation and black hole growth in SDSS J090543.56+043347.3 we find that both black hole and stellar mass are not expected to grow by more than 50 % between $z = 1.3$ and today – apparently, over this long period of time stellar and black hole mass do not change very much. However, what will still happen is that the orbits of the stars in SDSS J090543.56+043347.3 will be reshuffled by collisions with smaller companion galaxies from orbits in the stellar disk to the stellar bulge. This is supported by the fact that we see indications for a substantial gaseous disk component in the galaxy but expect that by $z = 0$ it will be largely a spheroidal galaxy without many disk stars.

We have now started to expand this novel analysis to a larger set of 15 further galaxies using a total of 80 hours of SINFONI time; 30 hours of guaranteed time invested by MPIA have already been observed, 50 fur-

Fig. II.3.4: Local $z = 0$ scaling relations (symbols and regression line) for black hole vs. dynamical host galaxy mass (Häring & Rix 2004, ApJ, 604, L89 with modified values by Sani et al. 2011, MNRAS, 413, 1479). Overplotted is our estimate of the dynamical galaxy mass of SDSS J090543.56+043347.3 vs. the black hole mass, once for an old literature value based on the MgII line (blue star) and vs. our new, improved black hole mass based on Hα. There is no discernable offset from the $z = 0$ relation.



ther hours were awarded in a general observing programme running until 2012. The total sample of 16 galaxies at redshifts $z = 1$ to 2.3 will enable us to make statements about the relative evolution of galaxies and their central black holes. If our conclusions from SDSS J090543.56+043347.3 are confirmed then massive galaxies from these redshifts can change predominantly by a redistribution of mass and even undergo a structural change, but without much addition of matter to the black hole or overall stellar mass. Over the past 9 billion years – for more than half of the age of our Universe! – most of these galaxies would have lived comparatively boring lives, subject to only very limited and slow change (The original publication is K. J. Inskip, K. Jahnke, H.-W. Rix & G. van de Ven, 2011, ApJ, 739, 90, "Resolving the Dynamical Mass of a $z \sim 1.3$ Quasi-stellar Object Host Galaxy Using SINFONI and Laser Guide Star Assisted Adaptive Optics").

Knud Jahnke, Katherine J. Inskip,
Hans-Walter Rix and Glenn van de Ven

II.4 Starbursting Dwarf Galaxies at High Redshift

Using the Hubble Space Telescope/Wide Field Camera 3 a team of astronomers led by MPIA scientists uncovered a previously unknown population of dwarf galaxies at $z \sim 2$ displaying extraordinary star formation activity. They are doubling their stellar masses in 10 million years, a pace that exceeds that of the Milky Way by three orders of magnitude.

Until now, the formation history of dwarf galaxies could only be studied through meticulously constructing color-magnitude diagrams of individual stars in nearby objects. Such case studies have been carried out for the past two decades and it is by now clear that the majority of stars living in present-day dwarf galaxies are old. In essence, the star formation history of dwarf galaxies does not appear to be markedly different from that of the universe as a whole: all galaxies, including dwarf galaxies, were forming stars at higher rates in the more distant past.

Observing high-redshift galaxies is the commonly adopted strategy to examine the galaxy formation process in more detail and also in a more direct manner. This has been done successfully for quite some time now, but results have been limited almost exclusively to massive, luminous galaxies. Dwarf galaxies are, usually, too faint to detect at any interestingly high redshift

Candels: an eye opener

This was suddenly changed by the unexpected discovery of an unusual yet apparently quite common type of object in new deep observations with the Hubble Space Telescope (HST). These observations were part of the largest HST survey ever undertaken: Candels (Fig.II.4.1). This international project aims at obtaining optical and near- infrared images over 'large' parts of the sky (about 700 square arcminutes) at exquisite depth (~27.5 AB mag). The combination of depth, area, spatial resolution and wavelength coverage make this a gold mine for examining the origin of galaxy structure and morphology (the Hubble sequence), the defining properties of the first galaxies that formed during (and presumably caused) reionization, and putting stronger constraints on the dynamical state of the universe through the discovery of Type 1a supernova at even larger cosmological distances than before.

This dramatic expansion of discovery space has immediately resulted in a number of interesting results, the most unexpected revelation being the topic of this article. Among the tens of thousands of high-redshift galaxies in the currently available images – the survey is about 50 % complete at the time of writing, and will be finished in 2013 – we noticed a number of $H \sim 25$ AB mag objects with very strange colors (Fig. II.4.1 and 2). Whereas they are red in $I - J$ (> 0.5 in AB mag, which is typical for a distant galaxy) they are extremely blue in $J - H$ (≤ 0.5).

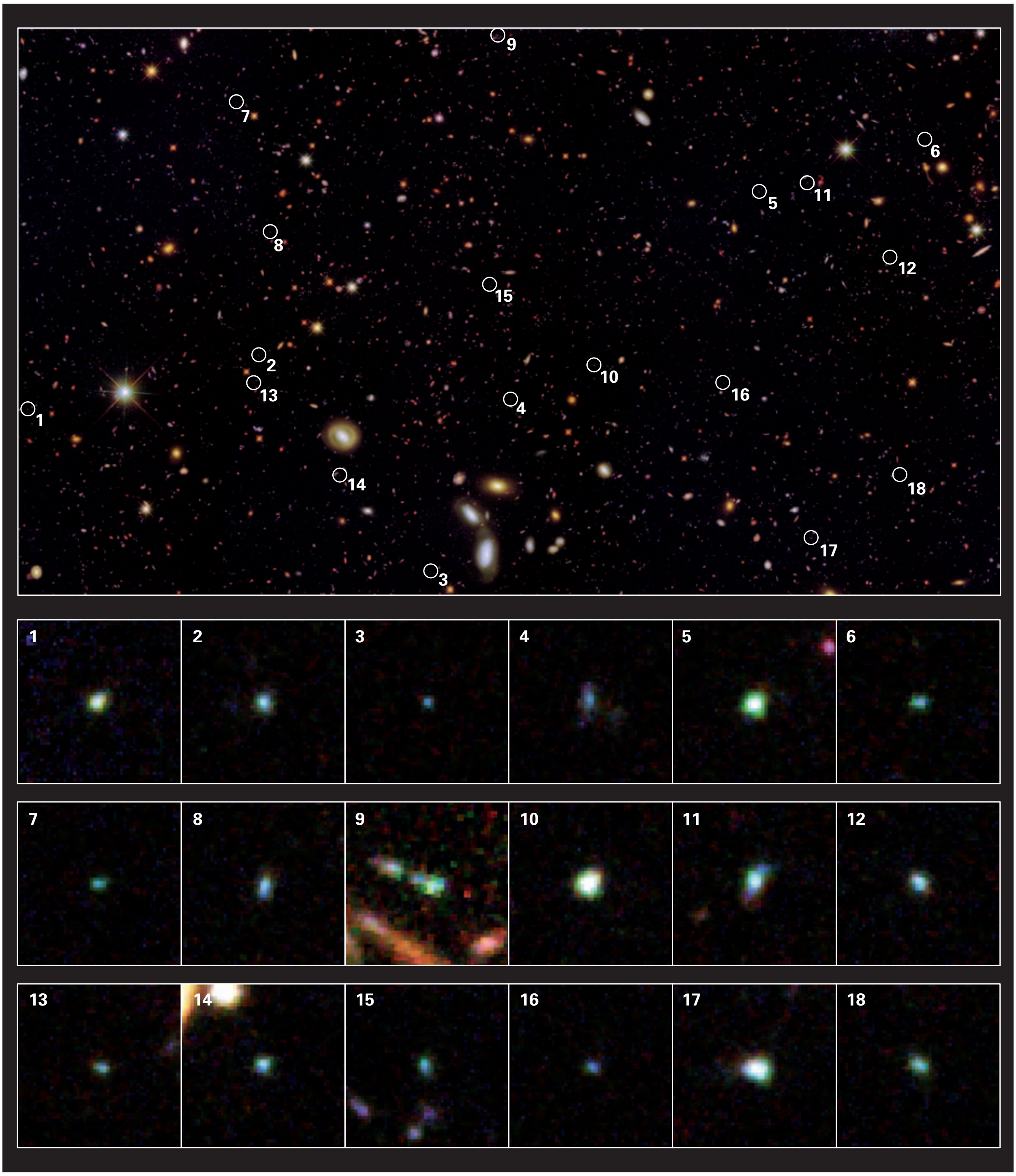
Extreme Emission Lines

Such extreme variations in the spectral energy distribution cannot be explained by any known continuum radiation processes, and we arrived at the conclusion that enormously strong emission lines must contribute considerably to the integrated light in the J band. The implication is that the equivalent width of this line (or lines combined) exceeds 1000 Å, which is unusual indeed.

Spectroscopic confirmation is, of course, essential to justify such an extraordinary claim. Usually, 25th magnitude objects are far too faint to obtain spectra for, but in the purported presence of bright emission lines (flux $\sim 10^{-16}$ erg s^{-1} cm^{-2}) this should, in fact, be quite straightforward. By chance, HST had already taken spectra for four of the 69 'extreme emission line galaxy' candidates, and all four candidates display bright emission lines at 1.3 – 1.4 μm (Fig. II.4.3). Moreover, the line fluxes are consistent with the excess light observed in the J band: emission lines explain the odd broad-band colors.

Interestingly, in all four cases the bright emission lines could readily be identified as the [OIII] doublet at restframe wavelengths λ = 4969 Å and λ = 5007 Å, flanked by Hβ at 4861 Å. This puts these objects in the redshift range z = 1.6 – 1.8, and from now on the working hypothesis will be that all 69 candidates we identified are in fact [OIII] emitters at z = 1.7. However, we should keep in mind that some of the candidates may be Hα emitters at $z \sim 1$, whereas other emission lines can be ruled out based on additional broad-band photometry at shorter wavelengths: none of the objects are so-called U or B-band dropouts, meaning that the Lyman break lies blueward of the U and B bands, limiting the redshift to $z \lesssim 2$. This rules out the other potentially very bright Ly α and [OII] emission lines.

In short, we have made a very strong case that we have identified a previously unknown population of $z \sim 1 - 2$ objects with extremely bright [OIII] (or Hα) emission lines. The question naturally arises what could cause emission lines with equivalent widths in excess of 500 Å in the rest frame. The two options are starbursts and active nuclei, that is, accreting black holes.



Credit: NASA, ESA, A. van der Wel (MPIA), H. Ferguson, A.Koekemoer (STScI), CANDELS team

Fig. II.4.1: The large false-color image shows an area of about 7′ × 10′ observed with HST/WFC3 and HST/ACS. The circles indicate the locations of 18 of the emission line dominated objects. The panels (3″× 3″ each) zoom in on these objects.

Surprisingly Large Numbers of Young Stars in Surprisingly Small Galaxies

While we cannot completely rule out that active galactic nuclei are responsible, it would be strange indeed to have such massive black holes in such small galaxies. This would require an accretion mode that is so far unknown and does not occur in the present-day universe. It is also entirely unclear what the descendants of such objects would be. In this sense, the starburst hypothesis is less outlandish: interpreting the observations as such puts, as we will see, these objects in the realm of dwarf galaxies in terms of their stellar mass and number density.

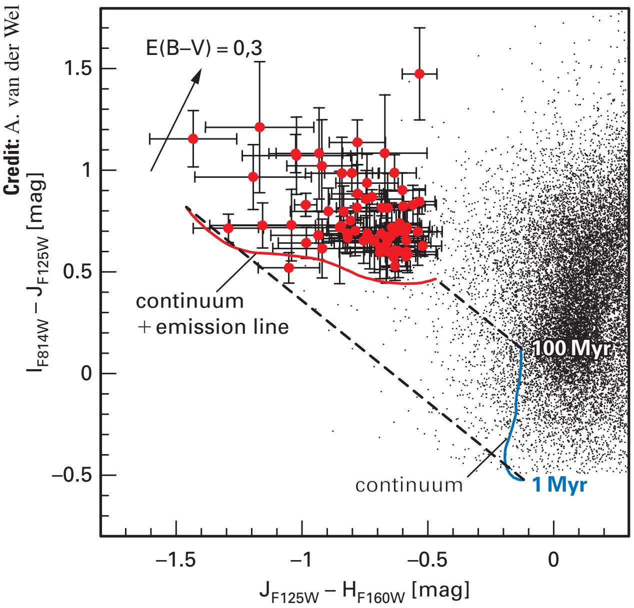


Fig. II.4.2: $I-J$ vs. $J-H$ color-color diagram of objects in CANDELS, highlighting with large red symbols with error bars those objects selected as extreme emission line galaxy candidates. They mainly differ from the main branch of galaxy colors by their blue $J-H$ colors. The blue line indicates the colors of the continuum radiation produced by a young population of stars (the ages are labeled). The red line includes the effect of a strong emission line on the colors. The selected objects have colors indicative of strong emission line contributions in the J filter.

Even when adopting the starburst hypothesis, it is immediately clear that these objects are all but normal. The only way to get such large line-to-continuum Flux ratios is to have a stellar population with an age of about 10 Myr. Usually, galaxy ages are measured in Gyrs, not Myrs. Given this age constraint, the luminosities imply stellar masses of around $10^8\,M_\odot$. Although it is plausible that an older population of stars exists we can rule out that these starbursts occur in much large, say, Milky Way type, galaxies. Rather, these must be truly low-mass galaxies, such that this population constitutes the first systematic detection of dwarf galaxies at high redshift.

Cosmological Context

Let us now consider the broader implications of the presence of 69 starbursting dwarf galaxies at $z \sim 1.7$ in CANDELS. To be somewhat more precise, assuming a redshift range of $z = 1.6-1.8$, their volume density is $\sim 4 \times 10^{-4}\,\mathrm{Mpc}^{-3}$. This makes them about 100 times rarer than present-day dwarf galaxies and they constitute only 0.1 % of the $\sim$10 Myr young stellar populations at that redshift if we consider galaxies of all masses.

While this may sound unimpressive it does not make these starbursts cosmologically irrelevant once we realize that they are very short-duration events: for every objects we see, there must be numerous similarly massive objects that are not undergoing such an intense burst of star formation at the time of observation but have had or will have one at some other time.

Let us formalize this argument and make two reasonable assumptions. The first assumption is that the observed bursts do not only occur at at $z = 1.7$ but at all redshifts $z = 1-4$, a period of roughly 4 Gyr. We know that similarly strong bursts are exceedingly rare at $z < 1$ but there is no reason to think that they do not occur over a much broader redshift range. With upcoming spectroscopic data from HST this assumption can be tested easily.

The second assumption is that between $z = 1.7$ and the present day these galaxies will not grow by an order of magnitude or more. That is, we will rely on the prediction of ΛCDM-based galaxy formation models that galaxies typically grow by a factor of several over that time span. That is, the descendants of the observed bursting galaxies at $z \sim 1.7$ are dwarf galaxies with masses $10^9\,M_\odot$. This assumption is more difficult to test, and all we can do now is rely on this model prediction.

By integrating the observed burst frequency at $z \sim 1.7$ over 4 Gyr ($z = 1-4$) we can derive the total number of bursts per unit cosmic volume as well as the total number of stars formed in this manner. By comparing the total number of bursts with the total number of dwarf galaxies in the present-day universe, it then follows that each present-day dwarf galaxy must have undergone two or three of such strong bursts over its life time, and, moreover, that the majority of the stars in present-day dwarf galaxies formed in these bursts. In other words, we propose that the star formation history of dwarf galaxies has been strongly burst-like: long periods of relative inactivity are interspersed with a small number of very strong bursts, mostly occurring at early times ($z > 1$).

Unsolved Riddles and Future Directions

The observations and our interpretation present a host of new questions, as well as speculation on the effect of such strong bursts on the galaxies and the dark matter halos that host them. First, hydrodynamical simulations cannot reproduce such strong bursts in such low-mass galaxies. It appears that something fundamental is lacking in our description of galaxy formation. Their mere existence implies the presence of large reservoirs of gas, and it is entirely unclear how to prevent this gas reservoir from forming stars before the burst commences, or, alternatively, how to assemble a large amount of gas on a very short time scale.

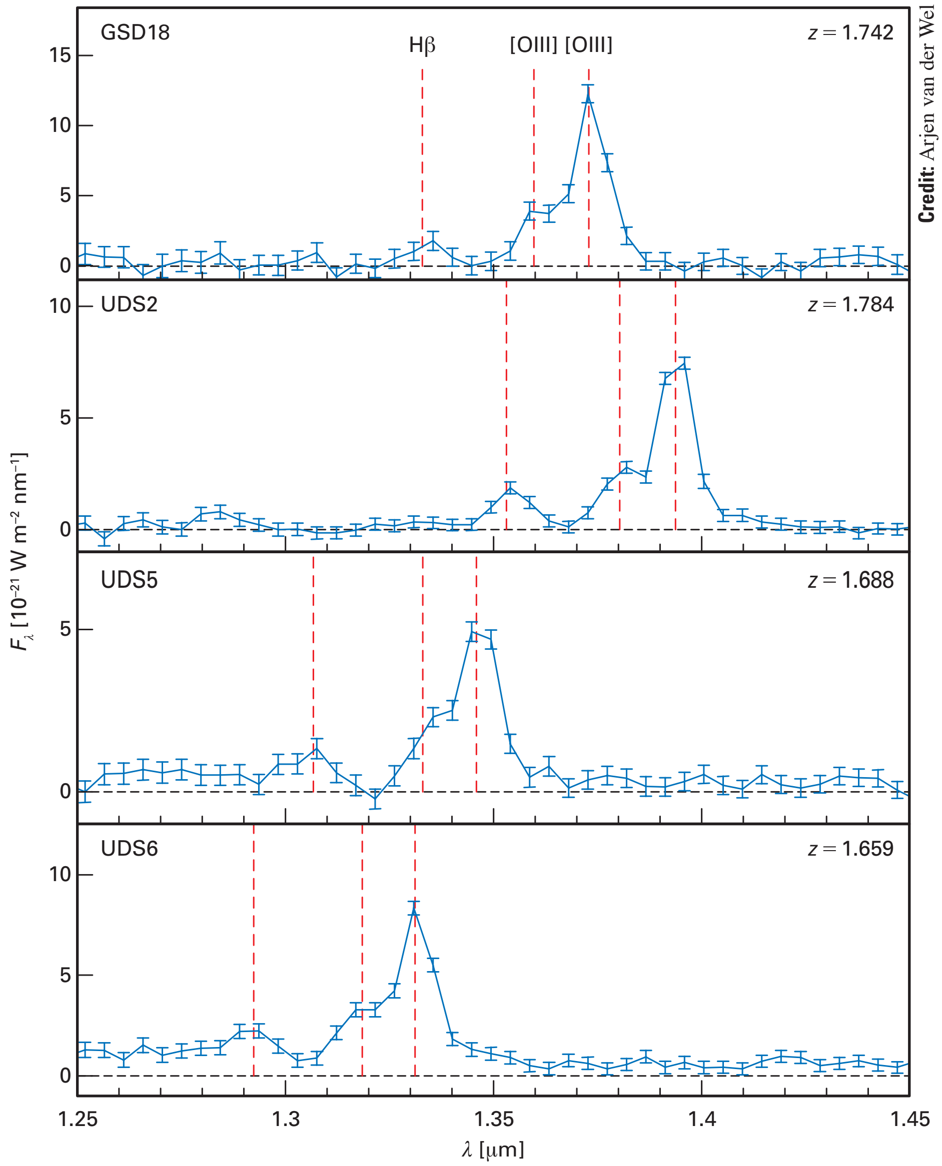


Fig. II.4.3: HST/WFC3 grism spectra of four extreme emission line galaxy candidates. In all cases, a strong emission is seen at around 1.35 μm, implying redshifts $z \sim 1.7$. The lines are readily identified as [OIII] by virtue of their asymmetry (the [OIII] line is a doublet that is marginally resolved at the low resolution of the grism, R ~ 100) and the presence of faint Hβ emission at the expected wavelength.

Another fascinating aspect of the bursts is the enormous amount of energy, produced by stellar winds and supernovae, that is injected into the interstellar medium. All still-present gas must be in the process of being blown out of the star-forming regions at a high rate, changing the very gravitational potential of the galaxy as whole. The consequences of this should be quite profound. The dark matter profiles may be altered in the sense that dark matter is removed from the center, producing so-called cored density profiles which are observed in low-mass galaxies in the vicinity of the Milky Way galaxy. It has long been argued that starbursts could provide the necessary feedback to alleviate the tension between observed rotation curves of dwarf galaxies and the strongly cuspy density profiles predicted by cosmological N-body simulations. The fact that we are now observing strong bursts in low-mass systems lends much credibility to this picture, especially because the bursts are all but rare.

An even more dramatic effect of the rapid outflow of large amounts of gas may be that the stellar body itself could become unbound. Such a process would obviously thwart our interpretation of dwarf galaxy formation: it suggests that the observed bursts do not have present-day descendants in the form of galaxies at all.

In summary, the newly discovered star bursts in distant dwarf galaxies are surprising in a number of ways, mostly because the level of star formation is extremely high for the galaxies' small masses. This provides a strong indication of how low-mass galaxies form, and may solve a long-standing problem in cosmology, that of the shallow central slopes of low-mass dark halos. Furthermore, many questions are raised that warrant further investigations. We will search for similar objects over a broader redshift range to find out how their frequency evolves with cosmic time, search for less extreme counterparts to sample different evolutionary stages of similar objects, and examine through high-resolution spectroscopy the metal content, dynamical masses, and ionization parameters of the most extreme bursts. What is perhaps most important is that we suddenly have a way to study dwarf galaxies at large cosmological look-back times. This new avenue will prove to be a valuable complement to the detailed studies that unravel the inner workings of nearby, present-day dwarf galaxies.

Arjen van der Wel, Hans Walter Rix
& the Candels team

III. Selected Research Areas

III.1 Planetary population synthesis

Planetary population synthesis is a new method that allows us to improve our understanding of planet formation and evolution by using statistical observational constraints provided by the extrasolar planets. They are now known in a sufficiently high number to treat them no more just as single objects, but also as a population characterized by a number of statistical distributions. With planetary population synthesis, the global effects of many different physical mechanisms occurring during planet formation and evolution can be put to the observational test.

Introduction

The number of known extrasolar planets has increased very rapidly in the last few years. Currently, there are several hundred confirmed exoplanets known, which were mostly found by the spectroscopic radial velocity technique. Additionally, there are more than two thousand candidates from the Kepler satellite which were detected with extremely precise photometric transit measurements. These detections have revealed an exiting diversity in the properties of planetary companions, which was not expected from the structure of our own planetary system, the Solar System. The detections have however not only revealed diversity, but also a number of interesting correlations and structures in the properties of the planets.

These insights were in particular possible thanks to the large number of planets now known. This allows for the first time to look at the (extrasolar) planets no more as single objects only but as a population that is characterized by a number of statistical properties. Understanding these statistical properties from the point of view of planet formation theory is one of the most important goals of planetary population synthesis.

The special interest in a statistical, population wide approach also comes from the fact that the knowledge about a single planet is often limited. For the majority of the extrasolar planets, still only a few orbital elements (semimajor axis, eccentricity,…) and a minimum mass are known (or a radius, but no mass in the case of the Kepler candidates). For a limited number of planets, which are typically planets around bright stars for which both the mass and the radius are known, more observational constraints can be derived like the mean density or the atmospheric structure, so that they are investigated in details. Also the Solar System provides a large body of precise observational constraints against which planet formation models must be tested. In order to benefit also from the large number, but individually limited data sets, statistical methods are necessary. This is important since several future surveys like the Gaia space mission or the Sphere survey with the VLT will yield additional, similar statistical data sets for comparisons.

The fundamental assumption behind planetary population synthesis is that the observed statistical properties (like the distribution of the planetary masses or semimajor axes) can be explained by studying the physical processes like the accretion of gas and solids occurring during the formation phase of the planets, given the initial conditions. These conditions for the planet formation process are the properties of the protoplanetary disk which are seen to surround most newly born stars. Observations of such circumstellar disks show that they come, as planets, with a variety of properties in terms of e.g. their mass or lifetime. For an individual planetary system, the properties of the protoplanetary disk from which it formed are mostly unknown, except maybe for the dust-to-gas ratio in the disk, which is likely correlated with the stellar metallicity that can be measured spectroscopically today. This means that the initial conditions are also only known in a statistical sense, which again makes a statistical approach appropriate.

Observational constraints

Fig. III.1.1 shows two of the most important statistical observational constraints. Explaining the structures seen in the two plots is one of the declared goals of planetary population synthesis. The left panels shows the (minimum) mass M versus the semimajor axis a of the exoplanets together with the planets of the Solar System. The extreme diversity, but also the existence of certain structures in the $a-M$ diagram is obvious. For exoplanets, the mass-distance diagram has become a representation of similar importance as the Hertzsprung-Russell diagram for stellar astrophysics. In the plot, one can distinguish several groups of planets. There are for example massive, close-in planets without equivalent in the Solar System. Such hot Jupiters are found around approximately 1 % of solar like stars (Mayor et al. 2011). A class of extrasolar planets that has only been detected in the last few years thanks to the progress in the observational precision are low-mass planets with masses between 1 to 30 Earth masses. These super-Earths and mini-Neptunes seem to be very abundant, since roughly 48 % of FGK stars are found to have such a companion with a period of up to 100 days (Mayor et al. 2011).

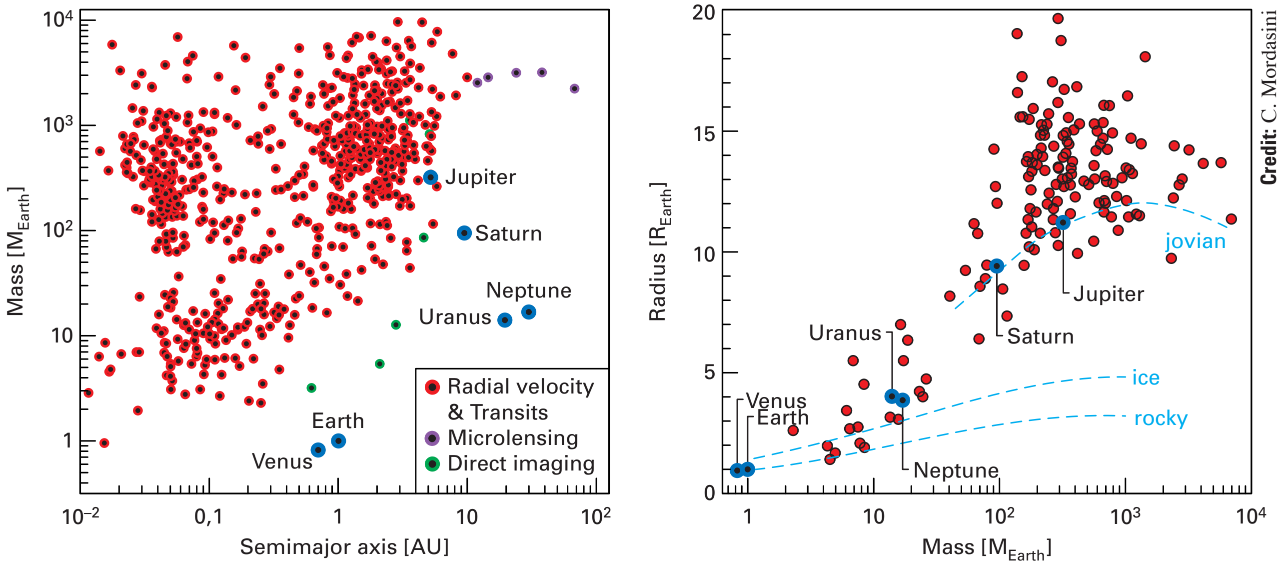


Fig. III.1.1: Two of the most important statistical observational constraints for planet formation theory. *The left panel* shows the semimajor axis – mass diagram of the extrasolar planets. The different colors indicate the observational detection technique. *The right panel* shows the observed mass-radius relationship of the extrasolar planets (*red points*), together with theoretical mass-radius lines for planets of different compositions. In both panels, the planets of the Solar System are also shown. Note that these figures are not corrected for the various observational biases, which favor for the radial velocity and the transit technique the detection of close-in, giant planets.

Since hot Jupiters are much more easily detected by both the radial velocity and the transit method relative to low-mass (respectively small) planets, their number is still lower in Fig. III.1.1, which is not corrected for the observational biases. Two statistical distributions which are linked to the a – M diagram are the semimajor axis distribution and the planetary mass function, which is studied below.

The right panel shows the radius of the extrasolar planets and the planets of the Solar System as a function of mass. The most recent breakthrough in the observation of exoplanets is that it has become possible to not only detect exoplanets, but also to start characterizing them. In this context, the planetary mass-radius diagram is probably the most central representation. The importance of the *M – R* plot stems from its information content about the inner bulk composition of planets which is the first, very basic geophysical characterization of a planet. In the Solar System, we have three fundamental types of planets, namely terrestrial, gas giant and ice giant planets. The imprint of the bulk composition on the radius is indicated by theoretical lines. Two lines show the theoretical mass-radius relationship for solid planets made of silicates and iron, and of water, while the third line shows the *M – R* for giant planets consisting mostly of H/He. Being able to understand and reproduce in a model this second fundamental figure is another goal of planetary population synthesis. The reason for the importance for formation theory stems from the fact that it contains additional constraints on the formation process, which we cannot derive from the mass-distance diagram alone. An example are the observational constraints coming from the *M – R* diagram on the extent of orbital migration. Efficient inward migration brings ice-dominated, low-density planets from the outer parts of the disk close to the star. These planets can be distinguished from planets consisting only of silicates and iron, which have presumably formed in situ in the inner, hotter parts of the disk. In future, the atmospheric composition of exoplanets as measured by, e.g., the planned EChO mission will provide additional, important constraints.

Another important goal of population synthesis that goes beyond the purely planetary properties is to understand the correlations between planetary and host star properties.

Population synthesis method

The general framework for population synthesis calculations is shown in Fig. III.1.2. With this framework, theoretical formation models can be tested how far they can reproduce the statistical properties of the entire known population. The most important ingredient is the planet formation and evolution model which establishes the link between disk and planetary properties. It will be addressed below. The second central ingredients are sets of initial conditions. These sets are drawn in a Monte Carlo way from probability distributions. These probability distributions represent the different properties of protoplanetary disks and are derived as closely as possible from observational results regarding the

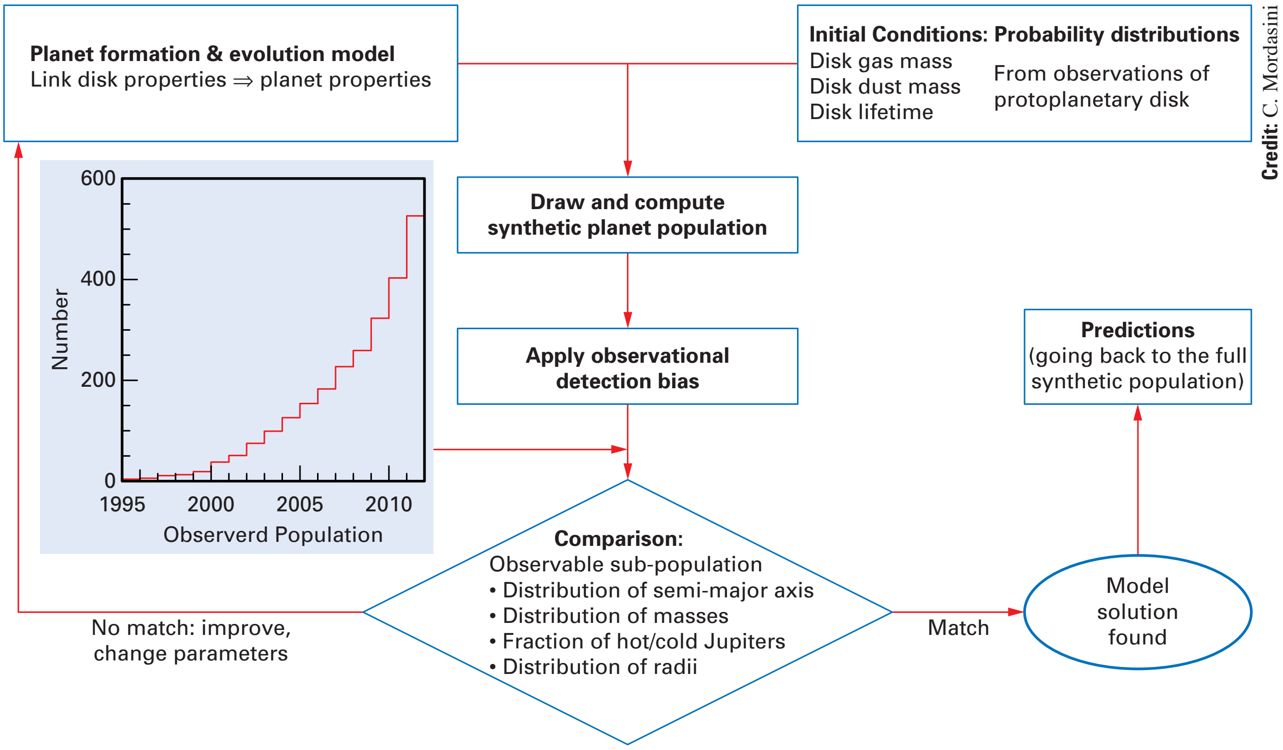


Fig. III.1.2: Flowchart of the population synthesis method.

disk. At least three different fundamental properties are considered: The mass of gas in the disk, the aforementioned dust-to-gas ratio, and the lifetime of the disk. Additionally properties can be the outer disk radius or the initial radial slope of the solid surface density.

For a given set of initial condition, the formation model is used to calculate the final outcome, i.e. the planetary system. This step is repeated many times (typically ∼10 000 times), leading to a population of synthetic planets. Many of these synthetic planets could not be detected by current observational techniques for example because their mass is too small (cf. Fig. III.1.1). In order to make quantitative comparisons with the observations, one must therefore apply in the next step a synthetic observational bias. This leads to the sub-population of detectable synthetic planets. This group is then compared in the following step with a comparison sample of actual exoplanets. Depending on the observational technique, different biases will be used. It is clear that the selection bias of a given observational survey should be known as well as possible for this step. This makes that large, well characterized surveys like e.g. the Kepler mission are of particular interest. For the comparison in the next step, various statistical methods can be used, like for example two-dimensional Komogoroff-Smirnofftests in the $a-M$ plane. This tests whether the actual and the synthetic planets are distributed in a similar way. Other quantities that are tested are the detection frequency, or the radius distribution. It can further be studied if correlations exist between the initial conditions, and the planet properties, and if similar correlation exist in reality. The most important observed correlation is the one between the stellar metallicity, and the frequency of giant planets. Giant planets are much more frequent around high metallicity stars, a correlation that can be reproduced with formation models based on the core-accretion theory.

Depending on the results of this procedure, one can judge if the formation model is able to reproduce certain observed properties, and thus probably catches some important mechanisms of planet formation. In the ideal case, one single population should be able to reproduce all observational constraints coming from many different techniques (radial velocity, transits, direct imaging and microlensing). In reality, there will be differences between the model output and the observations. The reason for these differences are then be analyzed, so that various physical descriptions of the mechanism occurring during planet formation and evolution can be tested. This can have the consequence that given physical mechanisms must be added to the theoretical model, or modified, or dropped as being inconsistent with observations. This is the fundamental mechanism by which planet population improves our understanding of planet formation and evolution.

In the case of a relatively good agreement between theory and observation, one can go back to the full underlying synthetic population and make predictions about planets or planetary properties that currently cannot be observed, like low-mass planets, or the internal composition. The capacity of population synthesis to allow for direct falsifiability with future observations is a strength of the method. Besides that, the predictions are also useful to estimate the yield of future instruments and surveys.

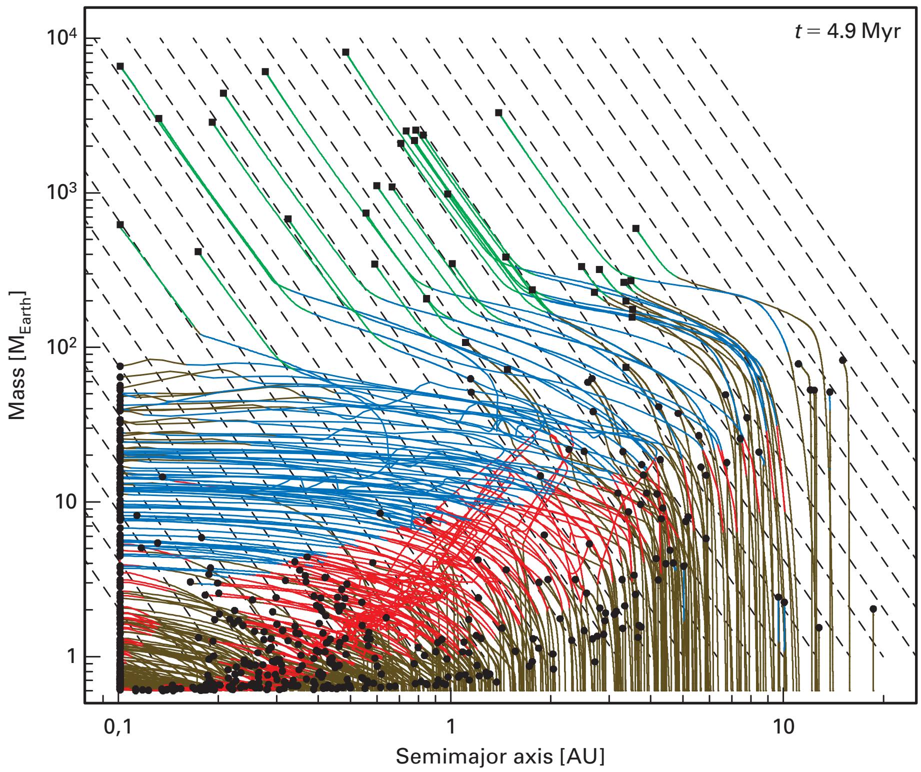
Planet formation models

On the observational side, usually only the initial conditions (the protoplanetary disks) and the final outcomes (the planets) are accessible to observations. With theoretical formation models, it is possible to bridge this gap at least on the theoretical side. The global, numerical models of planet formation used in population synthesis calculations try to cover the largest possible extent of important mechanisms. The various mechanisms like accretion or migration must be treated in an interlinked way, since they happen on similar timescales and feed back on each other. Ideally, the models would start with a protoplanetary disk at a very early stage when the solids are in the form of micrometer-sized dust grains, and yield as an output full-blown planetary systems at an age of several billions of years. This means that also the evolution of the planets over long timescales must be modeled, since we essentially observe planets a long time after they have formed. It is clear that these global models of planet formation and evolution involve important simplifications of the actual processes, and cannot describe all physical effects at the same level of detail as models dedicated to one single process. On the other hand, only combined models allow to see the interaction between different processes, and only they allow for direct comparisons with many observational constraints.

The global planet formation and evolution models used in population synthesis calculations are based on the so called core-accretion paradigm which states that first, solid cores are formed, some of which later accrete massive gaseous envelopes to become giant planets (bottom-up process), while the remaining cores collide to form both ice giants and terrestrial planets. The models address the following processes in a number of coupled computational modules:

1. A structure and evolution model for a gaseous protoplanetary disk. The gaseous disk model yields the ambient properties in which the planets form. The ambient pressure and temperature serve as outer boundary conditions for the calculation of the structure of the gaseous envelope of the planets. The structure of the disk is also very important for the orbital migration of the protoplanets, since the di-

Fig. III.1.3: Theoretical planetary formation tracks which show how planetary seeds (initial mass 0.6 Earth masses) concurrently grow and migrate. The colors indicate the different types of orbital migration. The position of the planet at the moment in time that is shown (4.9 Myrs) is indicated by black symbols. Some planets have reached the inner border of the computational domain at 0.1 AU.



Credit: C. Mordasini

rection and migration rate depends on the radial slopes of the temperature and the gas surface density. A good compromise for the numerical description of the disks (which are in reality very complex, 3D-structures driven by magneto-hydrodynamical processes) is provided by α-models, which describe the disk as a rotating, viscous fluid which has an axisymmetric structure.

2. A structure and evolution model for disk of solids. This model yields the size, dynamical state and surface density of the solid content of the disk. The solids are initially in the form of dust. This dust can grow in mass to form kilometer-sized planetesimals, but also get destroyed again in collisions. Additionally, they drift through the disk. These quantities are used to calculate the accretion rate of solids of the forming protoplanets.
3. An internal structure and evolution model of the planet. This model calculates the internal, 1-D radial structure of the interior of the planet. Both the solid part and the gaseous envelope of the planet are considered. The solid core is assumed to be differentiated and consist of layers of iron, silicates, and if the planet accreted outside of the snow-line, ices. For the gaseous envelope, only primordial H/He envelopes have been considered to date. During the formation phase, the model calculates the amount of gas a core can bind gravitationally. Low mass cores can only bind tenuous atmospheres, while cores more massive than roughly 10 Earth masses can trigger rapid, runaway gas accretion, so that a giant planet forms. After the formation phase, at constant mass, the temporal evolution i.e. the contraction and cooling is calculated, which yield radius and intrinsic luminosity of a planet.
4. The last module addresses the various interactions occurring during the formation process. These interaction and feedbacks are in large parts responsible for the complexity of the planet formation process. Various interactions have to be modeled:
a) the interaction of the planet and the disk of solids (planetesimals). The growing protoplanets not only accrete planetesimals, but also influence their dynamical state in terms of eccentricity and inclinations.
b) the interaction of the planets and the gaseous disk. Due to gravitational interactions, the gaseous disk exerts torques onto the planets, which causes them to undergo radial migration. This orbital migration is important in shaping the architectures of planetary systems.
c) the interaction of the solid and the gaseous disk. The drag felt by planetesimals causes the smaller bodies to drift inwards. The temperature structure of the gaseous disk also determines where in the disk which solids can condensate, which in the end influences the composition of the planets.
d) the interaction among planets. When several protoplanets form in vicinity, they influence each other via gravitational interactions. This can pump the eccentricity, lead to scattering events and even ejections of planets out of a planetary system. Migrating planets can get caught into mean-motion resonances, which can for example cause the outward migration of giant planets.
e) the interaction between the planets and the star. Planets at small orbital distances are subject to intense stellar irradiation. This irradiation modifies the internal structure of the planets, which affects their evolution. The intense irradiation can also cause planets to loose parts of their gaseous envelope.
f) the interaction between the star and the gaseous disk. The temperature structure of the gaseous disk is strongly influenced by the stellar radiation. The hard radiation by the star drives the internal photoevaporation of the disk, which is important for the lifetime of the disks. Close to the star, the magnetic field of the star can lead to the formation of a magnetospheric cavity, which can halt migrating planets.

For the different processes, already relatively well established physical descriptions are employed if possible. Some simplifications are necessary (e.g. for computational time restrictions), so that the global models rely on the results of models and theoretical studies which focus on one single aspect. In order to validate the models, dedicated simulations are made which focus on relatively well known individual planetary systems, in particular the Solar System. But also some extrasolar systems are studied individually, like for example the Kepler-11 system with at least six extrasolar planets, for which both the masses and the radii are known.

The global formation models should output as many observable quantities as possible, since in this case, one can use combined constraints from many techniques. The outputs should be: the mass, the orbital distance and the eccentricity (for comparison with radial velocity and microlensing results), the radius (which is a proxy for the bulk composition) for the comparisons with transit observations and the intrinsic luminosity for comparison with discoveries made with direct imaging.

An exemplary output from the global formation model used in the population synthesis calculations is shown in Fig. III.1.3. It shows formation tracks in the mass-distance plane. Planetary embryos are inserted at a given starting semimajor axis into protoplanetary disk of varied properties with an initial mass of 0.6 Earth masses. They then grow by accreting planetesimals and gas, and concurrently migrate due to the interaction with the gas disk. The distribution of the final positions of the planets (at the moment the protoplanetary disk goes away) is eventually compared with the observed mass-distance distribution (Fig. III.1.1). One can see that the outcome of the formation process is of a high diversity, despite

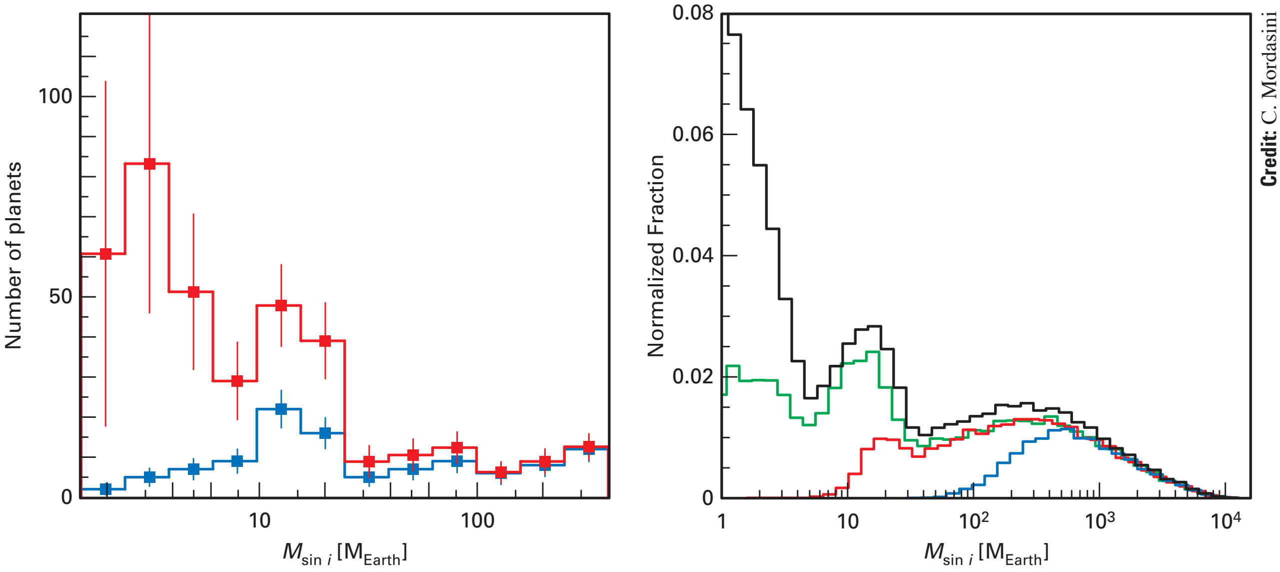


Fig. III.1.4: Comparison of the observed and the synthetic planetary mass distribution. The left panel shows the distribution of planetary masses as found with high precision radial velocity observations (Mayor et al. 2011). The blue line gives the raw count, while the red line corrects for the observational bias against the detection of low-mass planets. The right panel shows the planetary mass function as found in a population synthesis calculation. The black line gives the full underlying population, while the blue, red, and green lines are the detectable synthetic planets at a low, high, and very high radial velocity precision.

the fact that always exactly the same formation model is used. This is a basic outcome similar to the observational result. In Figure III.1.3, one can for example find tracks that lead to the formation of hot Jupiters. Most embryos however remain at low masses, since they cannot accrete a sufficient amount of planetesimals to start rapid gas accretion and become a giant planet.

Comparison with observations

Among the many outputs that can be compared with observations, one of the most fundamental results of population synthesis is a prediction for the distribution of planetary masses. It is obvious that the planetary mass function has many important implications, including the question about the frequency of habitable extrasolar planets. In the left panel of Fig. III.1.4, the planetary mass function is shown as derived recently from high precision radial velocity observations of FGK dwarfs (Mayor et al. 2011). It makes clear that below a mass of approximately 30 Earth masses, there is a strong increase in the frequency. Very low-mass planets of a few Earth masses are very frequent. The right panel shows the predicted mass function from population synthesis calculations of planets around a 1 $M_\odot$ star. Also in the theoretical curve, there is a strong change in the frequency at a similar mass as in the observations. This is explained by the fact that in this mass domain, planets start to accrete nebular gas in a rapid, runaway process. They then quickly grow to masses of $M \geqslant 100\,M_{\rm Earth}$. It is unlikely that the protoplanetary disk disappears exactly during the short time during which the planet is transformed from a Neptunian into a Jovian planet. This makes that planets with intermediate masses $\geqslant 30\,M_{\rm Earth}$ are less frequent ("planetary desert", cf. Ida & Lin 2004). The "dryness" of the desert is directly given by the rate at which planets can accrete gas, while the mass where the frequency drops represents the mass where runaway gas accretion starts. We thus see how the comparison of synthetic and actual mass function constrains the theory of planet formation. We further note that model and observation agree in the result that low-mass planets are very frequent.

A typical example how planet population synthesis can be used to study the global effects of a given physical mechanism is shown in Fig. III.1.5. The plot compares the observed distribution of radii of planets inside of 0.27 AU as found by the Kepler satellite (Howard et al. 2011) with the radius distribution in three different population synthesis calculations. The three calculations are identical except for the value of $f_\varkappa$. This parameter describes the reduction factor of the opacity due to grains relative to the interstellar value. A value of $f_\varkappa = 1$ means that the full interstellar opacity is used, while $f_\varkappa = 0$ means that we are dealing with a grain-free gas where only molecular and atomic opacities contribute. These opacities are used when calculating the internal structure of the planets. There, the strength of the opacity is important for the rate at which planets can accrete primordial H/He envelopes. At low opacities, the liberated gravitational potential energy of the accreted gas can be easily radiated away, allowing the envelope to contract, so

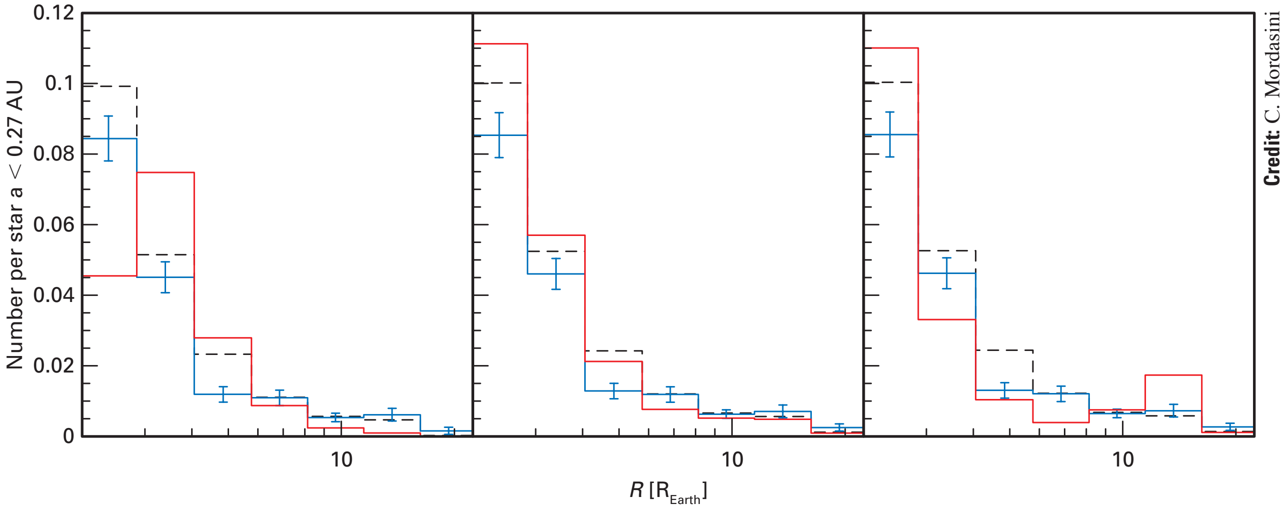


Fig. III.1.5: Tests of the impact of the opacity due to grains in the protoplanetary gas envelope on the planetary radius distribution at 5 Gyrs. In all panels, the blue line with error bars shows the distribution of radii as found by the Kepler satellite. The red line shows the synthetic distribution for a full, reduced, and vanishing grain opacity (*left to right*).

that new gas can be accreted. The opacity is thought to be reduced in protoplanetary atmospheres, since grains grow and then settle into the deeper parts of the envelope where they are vaporized.

Concentrating on the radius bin in Fig. III.1.5 that contains the giant planets at about 1 Jovian radius, ($\approx$ 11 Earth radii), we see that with full grain opacities, there are too few synthetic planets relative to the observations. With vanishing grain opacities, the efficiency of giant planet formation is on the contrary too high in the model relative to the data. This general effect is of course expected, but only with population synthesis it can be quantified, and directly compared with observations. A relatively good agreement with the observations is found with a $f_{\varkappa} = 0.003$ (middle panel). The comparison shown here thus indicates that grain growth is effcient, so that the opacities are much smaller than in interstellar space, but that grains still contribute to a certain degree. The plots also demonstrate that the opacity also has an important effect on the frequency of planets with small radii, corresponding to low-mass planets. This is because with a different opacity, the mass growth history of an embryo is different, so that the planet has at a given moment in time a different mass in the three simulations. The mass in turn influences the rate of orbital migration, and the migration regime the planet is in. This makes that in the three populations different types of planets migrate close to the star, resulting in different radius distributions also at small radii.

In summary, the comparisons with the observed po-pulation shows that the mass distribution of extrasolar planets (at least for masses $\gtrsim 10 M_{\text{Earth}}$) can be approximately reproduced with the synthetic populations. Also the observed positive correlation of stellar metallicity and the frequency of giant planets can be reproduced at least in a quantitative way. More important differences exist for the distribution of semimajor axes. This indicates that the physical processes that govern the accretion of mass are currently better understood than the processes that control the distribution of orbital distances. Such differences are not a surprise, since many of the processes that influence e.g. the orbital migration are still only understood in a very rudimentary way, and the description of them in the models are insecure.

Summary and outlook

Planetary population synthesis is a new method that allows to improve our understanding of planet formation and evolution by using statistical observational constraints provided by the extrasolar planets which are now known in a suffcient number to treat them as a population. With it, the global effects of many different physical mechanisms occurring during planet formation and evolution can be put to the observational test.

The first group of extrasolar planets which was known in suffcient numbers were giant planets detected by the radial velocity method. Population synthesis calculations therefore initially concentrated on studying the mass and semimajor axis distribution of this type of planets. After this first phase of extrasolar planet detections, recent observational results now start to provide a first physical characterization of planets outside of our Solar System. Important results are the observational determination of the planetary mass-radius relationship (Fig. III.1.1) and the atmospheric structures of transiting exoplanets. Another class of new constraints comes from the direct imaging method, which yields the intrinsic luminosities of young giant planets.

This new observational data provides important new impulses to planet formation and evolution theory, since

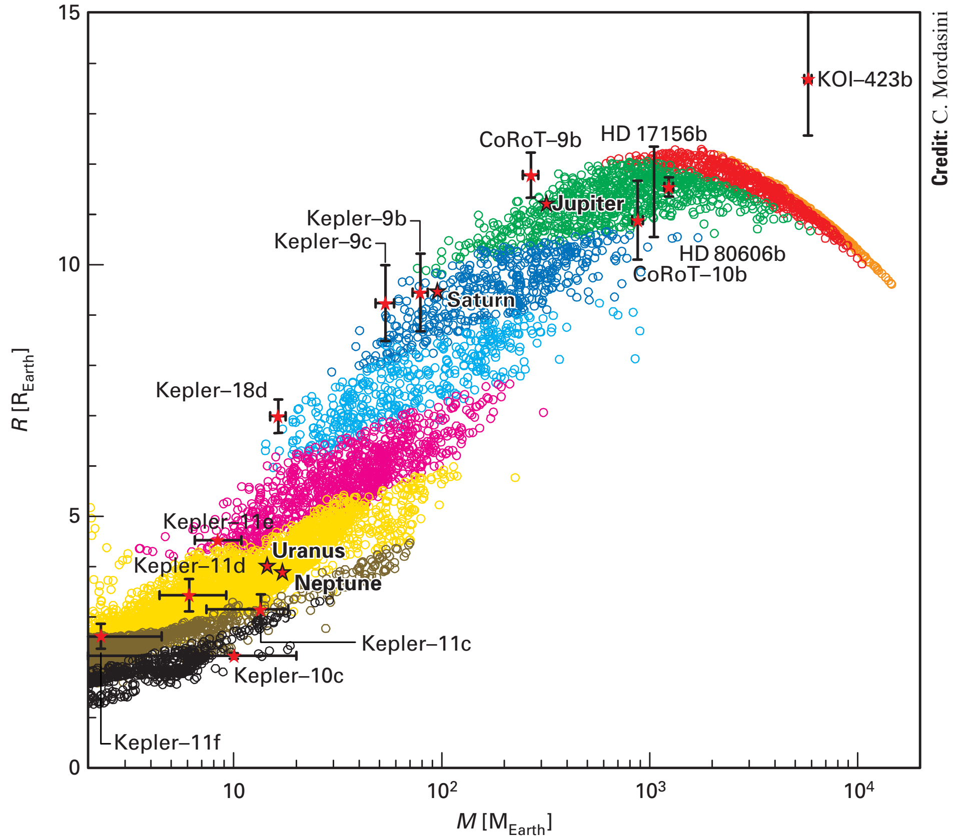


Fig. III.1.6: Mass-radius diagram of synthetic planets with a primordial H/He envelope at an age of 5 Gyrs together with all planets in- and outside of the Solar System with a known mass and radius, and a semimajor axis of at least 0.1 AU (as in the model). The colors indicate the fraction of heavy elements in the synthetic planets. The black symbols (bottom) for example correspond to solid-dominated low-mass planets which contain at most 1 % of H/He, while the most massive planets (orange, top) consist of at least 99 % H/He.

it adds constraints that go beyond the position of a planet in the mass-distance plot. Fig. III.1.6 shows a comparison of the observed mass-radius relationship of actual and synthetic planets as found in a recent population synthesis calculation. These calculations do not only model the formation of the planets, but also their evolution once the protoplanetary disk has disappeared. The global shape of the planetary mass-radius relation can be understood from the core accretion paradigm, and the basic properties of matter as expressed in the equations of state: Low-mass planets can only bind tenuous H/He envelopes, since their Kelvin-Helmholtz timescale for envelope contraction during the formation phase is long compared to the typical lifetime of a protoplanetary disk. Therefore, the top left corner in the $M-R$ plane remains empty, as no low-mass, gas-dominated planets come into existence. Also the bottom right corner remains empty. This is due to the fact that massive cores necessarily cause rapid runaway gas accretion, so that their composition is dominated by envelope gas. No massive, solid dominated planets come into existence that would populate the bottom right corner. One notes that the synthetic and most actual planets populate the same location in the mass-radius plane.

From the position of a planet in the mass-radius relationship, it is possible to deduce (within some limits due to degeneracies) the bulk composition of a planet. This is due to the fact that for a given total mass, planets with a higher fraction of solid elements (iron, silicates, and possibly ices) relative to H/He have a smaller radius. The plot shows that depending on the mass range, there are many different associated radii, reflecting a large diversity in potential interior compositions. These different compositions are in turn due to the different formation histories. It is for example found that planets at large distances typically contain a higher fraction of solid elements, since the mass of planetesimals available to accrete (the isolation mass) increases for currently accepted disk models with distance.

The interior structure of a planet also varies depending on the place where it has accreted matter. Planets that accrete mainly outside of the ice line will contain large amounts of ices. This leaves traces in the bulk composition, and possibly also in the atmospheric composition. Future global models of planet formation and evolution should therefore include detailed descriptions for the (chemical) composition of planets, and consider for example also other envelope types than just primordial H/

He envelopes. They will also be much more detailed in the description of many other effects occurring during planet formation, like e.g. the interactions of many planets that are forming concurrently, or the effects of atmospheric mass loss due to stellar irradiation. When used in planetary population synthesis calculations, these models will yield many testable predictions for all major observational techniques. This is important in a time where many surveys both from space and from the ground are expected to yield large amounts of additional data on both the global statistics and the physical characteristics of extrasolar planets. Seeking for the theoretical models which best explain these combined data sets will be a fruitful approach towards a better understanding of planet formation and evolution.

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III.2 Formation of star-forming structures in the interstellar medium

New stars are born in the cold and dense molecular clouds that are present "everywhere" in the Universe. How these molecular clouds are formed and how they evolve are key questions in the current efforts to establish global laws that regulate the star formation process. The fundamental physical processes that are responsible for the evolution of molecular clouds can be studied through accurate measurements of how the material in them is distributed. Here we review our research on this topic.

Molecular clouds of the interstellar medium (ISM) provide the environments where new stars in the Universe can be born. There is an intricate, two-way connection between the physical structure of molecular clouds and star formation inside them. On the one hand, star formation is very concretely driven by the molecular cloud structure: how much and how rapidly a cloud can form stars depends crucially on how exactly the material in it is organized. However on the other hand, the star-formation process itself is a great sculptor of molecular clouds. Once started in the cloud, active star formation will efficiently restructure the cloud material with jets and outflows from young stars, radiation pressure from massive stars, and powerful shock waves from dying stars. These processes rapidly erase the structural characteristics of the clouds that were prevalent before the star formation started in them.

How exactly the molecular clouds in the ISM come to be and what are the physics driving their formation and evolution are fundamental open questions in the field of ISM- and star formation-research today. One way to study these processes is borne out by the fact that different physical mechanisms cause the material in the clouds to be organized in different ways. Therefore, accurate measurements of the clouds mass distribution lead to information on what mechanisms are responsible for shaping the clouds.

What regulates the structure-and star formation in molecular clouds?

We know today that the molecular clouds are formed and shaped primarily by the interplay of three forces: the turbulent energy in the ISM, gravitational forces, and the support of magnetic fields within them. Schematically, the pathway of gas in galaxies towards star formation begins from large-scale instabilities, e.g. from atomic gas flows colliding at supersonic velocities, resulting in shocks, and further, to strong density fluctuations in

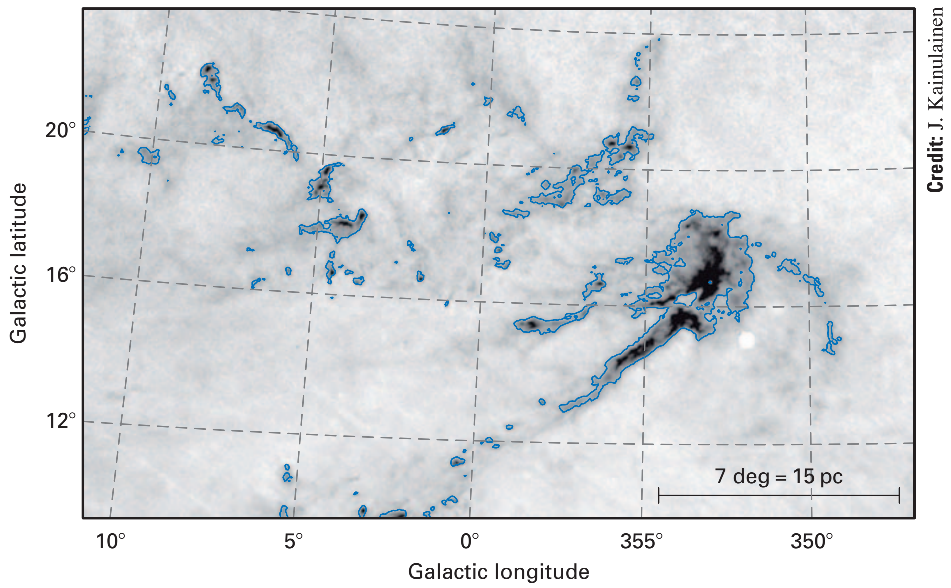


Fig. III.2.1: Dust extinction map of the Ophiuchus star-forming region. The dust extinction can be used as a tracer of the gas column density in molecular clouds, and hence, as a tracer of their mass distributions. In Kainulainen et al. (2009, A&A, 508, L35) and Kainulainen et al. (2011, A&A, 530, A64), we derived extinction maps for 23 nearby molecular clouds and studied with the maps the probability distributions of column densities in them. Based on our findings in these works, we proposed a new evolutionary scheme for molecular clouds in which the pressure from the diffuse medium surrounding denser clumps in the clouds plays a significant role in the cloud evolution.

the post-shock gas. Some of these density fluctuations contain enough material so that the (still atomic) gas in them becomes well-shielded from any outside sources of radiation. This enables the formation and survival of molecules, thereby giving birth to molecular clouds.

Statistical arguments suggest that stars begin to form in molecular clouds relatively rapidly after their formation. Yet in this short time, the clouds evolve from a diffuse, barely molecular state to a state of clearly higher density and average central concentration. The most important consequence of this evolution and gas compression is that some density fluctuations in the cloud are massive enough to become locally gravitationally supercritical. These extreme density enhancements, commonly referred to as dense cores, undergo a gravitational collapse and ignite the actual star-forming process.

The analytic and numerical theories of how star formation proceeds in molecular clouds aim at explaining how the interplay of turbulence, gravity, and magnetic fields can produce dense cores in the clouds. What is currently not well-known in these theories is how strong the impact the different forces have on the molecular cloud structure at different stages of the clouds evolution. As a result of this lack of knowledge, some fundamental questions remain open: How efficiently molecular clouds convert their gas into dense cores? At what rate this conversion takes places? What keeps the clouds from collapsing rapidly under their own gravitation? These questions are of crucial importance, as they ultimately set the star formation efficiencies and -rates of the clouds and of galaxies. The questions are also closely linked to understanding the origin of statistical properties of stars such as their initial mass function (IMF).

From the observational point-of-view, constraining the roles of different cloud-shaping processes translates into determining the mass distribution, the kinetic energy content, temperature, and the magnetic field strength of cloud structures across entire molecular cloud entities. These data can be, in some cases, used directly to assess the strengths of processes acting in the clouds. However more often, the data must be used indirectly by comparing them to predictions resulting from numerical and/or analytical theories. In particular, such studies should be performed for young clouds that only show little or no star-forming activity at all. This is the only way to reach the maternal cloud structure that still bears the imprints of the processes that acted during the formation of the cloud. The scientists at MPIA are actively studying this defining stage of molecular cloud evolution.

Probing the clouds density structure with the extinction of starlight

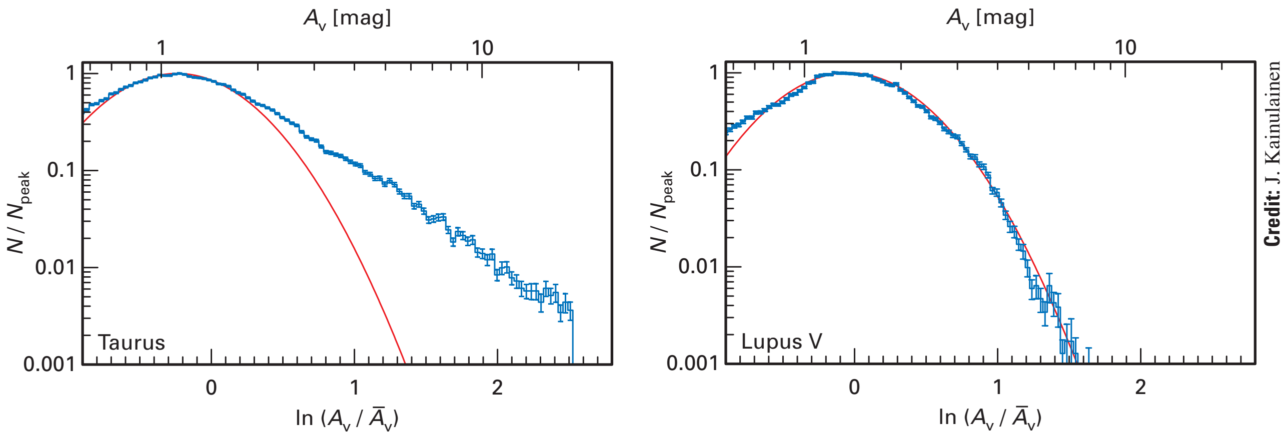
One powerful tool to study how the material is distributed in molecular clouds is to measure the extinction of background starlight by dust towards them. This technique, developed primarily during the past decade, also with the help of MPIA scientists, is based on observations of a myriad of stars that shine through molecular clouds at near-infrared (NIR) wavelengths. When the light from the stars travels through the molecular cloud, the dust that is mixed with the gas in the cloud absorbs and reflects away part of the light. This extinction of starlight is wavelength dependent, causing the light that travels through the cloud to redden. The amount of reddening depends linearly on the amount of intervening dust, and can therefore be used as a measure of total mass along the line-of-sight to the star that emitted the light. Thus, observing the reddening towards tens of thousands of stars behind a molecular cloud complex can be converted into a map describing its mass distribution.

This NIR dust extinction mapping technique has some profound advantages compared to other commonly used techniques to measure mass distributions. For one, the technique is applicable over a relatively wide column density range that extends from diffuse, partly atomic material ($N(H_2) \sim 1 \times 10^{21}\,cm^{-2}$) in the clouds to the column densities of dense cores ($N(H_2) \sim 50 \times 10^{21}\,cm^{-2}$). It also does not depend on the temperature of gas or dust in the cloud, which is a major advantage compared to measurements of column densities via dust continuum emission, e.g., with the HERSCHEL satellite. Finally, the technique is based on photometric data of stars in the NIR, which type of data is relatively straightforward to gather and analyze with the current observational techniques.

Figure III.2.1 shows as an example the dust extinction map derived for the Ophiuchus star-forming cloud by Kainulainen et al. (2009, A&A, 508, L35). The data have an angular resolution of 2′, which at the distance of Ophiuchus is about 0.07 pc. The data show particularly well the diffuse structures surrounding the sites of star formation in the complex, thus allowing a view of the structures that envelope the dense cores inside where stars in the cloud are forming. This technique to trace the mass in molecular clouds has been exploited in several works by MPIA scientists, including studies of the fragmentation of filamentary molecular clouds (Schmalzl et al. 2010, ApJ, 725, 1327; Beuther et al. 2011, A&A, 533, A17), properties of young star populations inside molecular clouds, (Sicilia-Aguilar et al. 2011, ApJ, 736, 137), and the temperature structure of isolated molecular cloud cores (Stutz et al. 2010, 518, L87; Nielbock et al. submitted).

What does the clouds density structure tell about the physical processes shaping it?

As described earlier, density fluctuations in newly-formed molecular clouds act as seeds of dense cores that can further evolve towards gravitational collapse and star formation. The occurrence of these fluctuations can



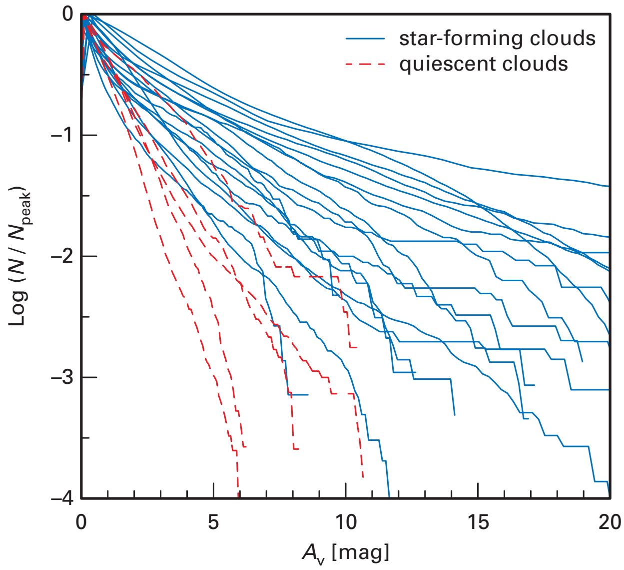


Fig. III.2.2: *Top:* Column density PDFs for the Taurus and Lupus V molecular clouds. Taurus is an active star forming cloud, but Lupus V shows very little signs of star formation. *Left:* Cumulative mass distributions of 23 nearby molecular clouds. The star-forming clouds are shown with blue curves and non-star-forming clouds with red curves. The figure shows that the star-forming clouds contain greatly more material at high column densities compared to the non-star-forming clouds.

be described efficiently with the help of the mass distribution data derived using the dust extinction mapping technique. This topic has been pursued actively in MPIA recently. The frequency at which density fluctuations occur in a molecular cloud can be expressed through the so-called probability density function (PDF, hereafter) of volume densities in the cloud. This function describes the probability of a volume dV to have a density between [ϱ, $\varrho + d\varrho$]. The PDF function forms a cornerstone for many analytic star formation theories, in which its role is to describe the basic statistics of the density field. In these theories, the function is directly linked to the formation rate of self-gravitating dense cores, and hence, to the rate at which new stars form.

Theoretical and numerical works predict that the volume density PDF takes a *log-normal* shape in isothermal, turbulent media not significantly affected by the self-gravity of gas or magnetic fields. However, in the presence of strong gravitational forces, non-isothermal equation of state, or strong magnetic field support, deviations (usually an excess) to this shape can develop, especially at the high-density side of the PDF. Since the functional form of the PDF is directly linked to the ability of the media to form dense cores, it is crucially important to constrain the PDF through observational data. However, because of the observational restrictions such works have been rare in the past.

Observations are always performed in the two-dimensional plane of the sky and they can only recover *column densities*, not directly three-dimensional *volume densities*. However importantly, some properties of the volume density PDFs can be derived through observations of their column density PDFs. For example, a log-normal shape of the volume density PDF should remain invariant in transformation to column densities. Similarly, under certain conditions, it is possible to derive the shape parameters of the volume density PDF, i.e., mean and dispersion, from the column density PDF. In other words, *by measuring accurately the column density PDFs in molecular clouds it is possible to present constraints to both processes that regulate structure formation in molecular clouds and the theories that use the function as an input in predicting star-forming rates and -efficiencies in the clouds.*

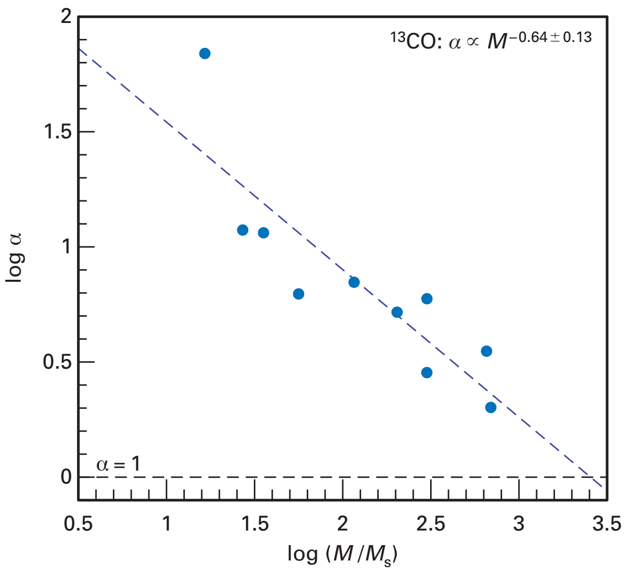
What do the column density PDFs in molecular clouds then look like? The MPIA scientists performed recently the first systematic study of the column density PDFs in molecular clouds (Kainulainen et al. 2009, A&A, 508, L35; Kainulainen et al. 2011, A&A, 530, A64). This study presented mass distribution data for 23 nearby molecular clouds, derived using the NIR dust extinction mapping technique. Most importantly, the work showed that the PDFs of star-forming and non-star-forming clouds are fundamentally different from each others, so that only non-star-forming clouds have column density PDFs that are consistent with a log-normal shape.

Star-forming clouds deviate from this shape by having a significantly higher relative amount of high-column density fluctuations. The result is illustrated in Fig. III.2.2, which shows the column density PDFs for a typical star-forming (Taurus) and a quiescent (Lupus V) cloud. In the context of turbulent molecular clouds, the result suggests that only the low-column density regions in the clouds are dominantly shaped by turbulent motions, while higher-column density regions are affected more crucially by some other process. Interestingly, the PDFs of active star-forming clouds have all rather similar PDFs (similar to that of Taurus in Fig. III.2.2). This suggests that there exists some fundamental state that the cloud structures have to reach before significant star formation can occur.

The difference between the PDFs of quiescent and star-forming clouds also means that star-forming clouds contain higher relative amount of high-column density material than quiescent clouds. This result is illustrated in the lower left panel of Fig. III.2.2, which shows the cumulative mass functions of a sample of molecular clouds. The cumulative mass functions describe what fraction of the clouds mass is at column densities higher than the value at x-axis. The star-forming clouds that are shown with blue curves in Fig. III.2.2 harbour a clearly higher fraction of material at high column densities than quiescent clouds that are shown with red curves.

An immediate question arising from the observed PDFs is: What physics exactly cause the deviation from the log-normal shape in the PDFs on star-forming clouds? As described earlier, a log-normal column density PDF

Fig. III.2.3: Virial parameters of clumps that represent structures in the "tail" part of the column density PDFs as a function of the clumps' mass. Virial parameter of $\alpha = 1$ reflects equipartition between gravitational and kinetic energies of the structure. The relation shows that the structures are not significantly supported by their self-gravity, and it also suggests that external pressure might play a significant role in supporting them.



Credit: J. Kainulainen

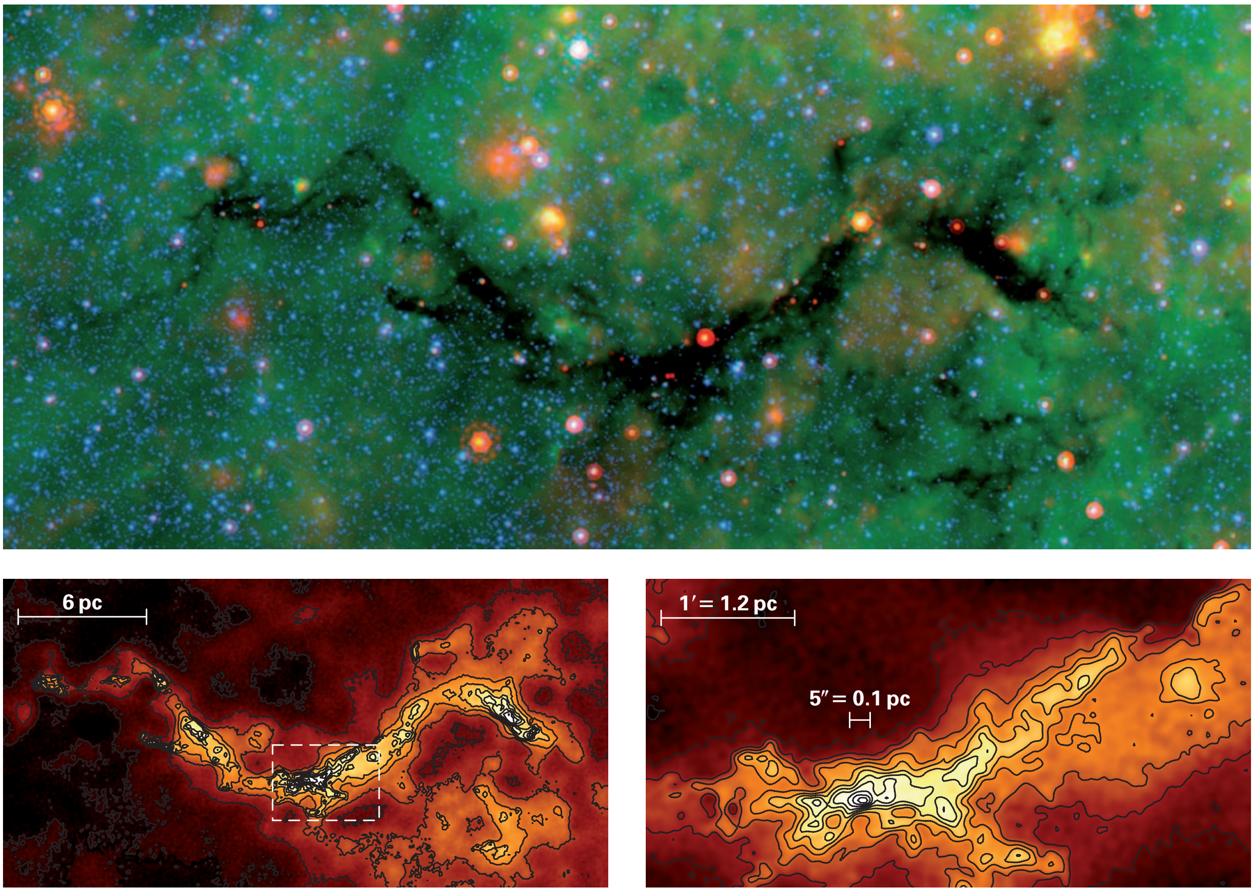
is expected for turbulent, isothermal media, with possible deviations caused by various other processes. An intuitive option would be to relate the deviation to self-gravitating structures forming in the cloud. However, the deviation from the log-normal form seems to occur at column densities clearly lower ($A_V \sim 2-5$ mag) than traditionally connected to self-gravitating dense cores. This question was further looked into by Kainulainen et al. (2011, A&A, 530, A64), and interestingly, it seems that self-gravity does not provide significant support for structures above the threshold of $A_V \sim 2-5$ mag. This is illustrated in Fig. III.2.3 which shows the virial parameters of structures above the threshold. Virial parameters are clearly higher than unity, which indicates they are not gravitationally bound. Instead of self-gravity, the structures above that column density can be significantly supported against dispersal by the external pressure that is imposed to them by the massive, but more diffuse, cloud material surrounding them. This inwards pressure can roughly match the internal thermal pressure of the structures, making them more long-lived, or even quasi-stable. With this mechanism, structures formed in a turbulent, atomic flow could survive for the time required for molecule formation, cooling, and hence decreased thermal support. This can be followed by further accretion of material, structure formation, and eventually star formation to take place.

Summarizing the above, star-forming clouds seem to contain pressure-confined structures that also leave their imprint to the column density PDFs. Non-star-forming clouds do not contain such pressure-confined structures. This leads to a picture in which *the formation of pressure-confined structures introduces a pre-requisite for star formation*. This picture emphasizes the role of the pressure from the large-scale, diffuse molecular cloud for the stability of structures forming in the cloud. Subsequent studies on the dynamic structure of molecular clouds that cover the regime of both the dense cores and diffuse material surrounding them are needed to affirm the global nature of this picture. Such studies are currently in progress at MPIA.

From low-mass to high-mass star-forming regions

The results discussed above are best suited to describe structure formation in relatively low-mass clouds that form low-mass stars, much like that of our own Sun. It is an imminent question whether the same results hold when the birth-places of high-mass stars or star-clusters are considered.

In the case of massive stars, the need to reach the quiescent stage of cloud evolution to study the natal cloud structure is even more pressing than in the case of low-mass clouds, because of the more violent nature of the high-mass star formation. The best candidates for the future high-mass star formation are the dense and massive



Credit: J. Kainulainen

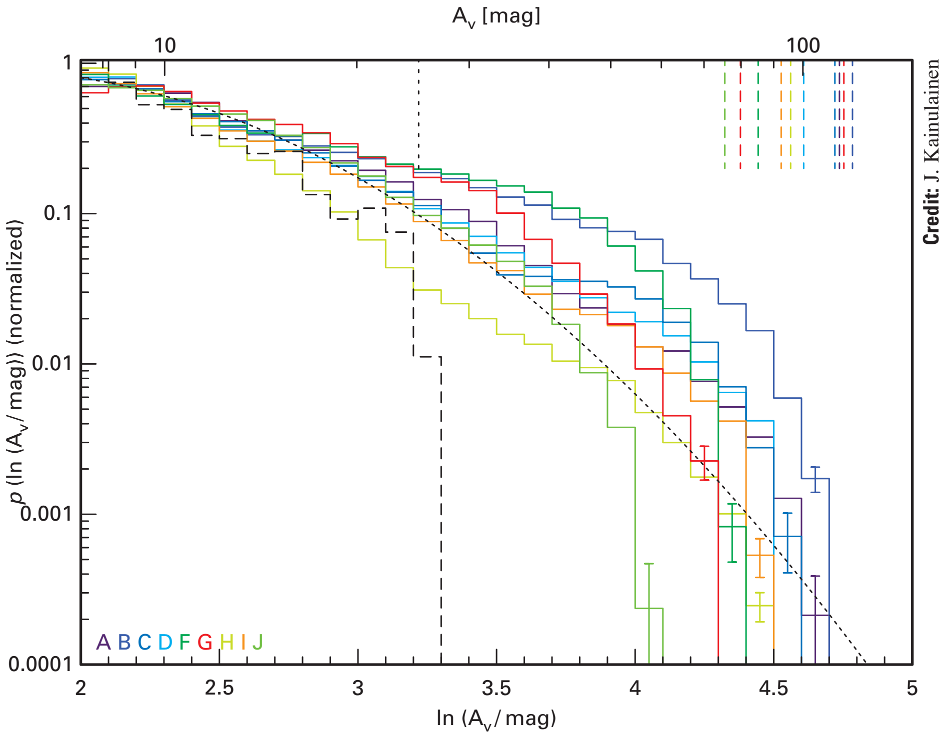
Fig. III.2.4: Infrared dark cloud G11.10-0.10, also known as "The Snake". *The top image* shows a three-color-composite made out of 8 µm, 24 µm, and 70 µm band data from the Spitzer/Glimpse + Mipsgal surveys (credit: www.alienearths.com/glimpse). Bottom Left: Dust extinction map of the cloud derived using a new technique that combines near-infrared and mid-infrared data. *Bottom Right:* A zoom-in to the center region of the map, showing the multitude of structures at the size-scale of the dense cores in the cloud (i.e., ~ 0.1 pc).

cores inside Infrared Dark Clouds (IRDCs, hereafter). These objects, discovered only relatively recently, harbor dense cores whose sizes and densities match those of the "hot cores" that harbor very young massive stars, yet they seem to be cold and contain no point sources. Consequently, it seems clear that at least some fraction of the IRDCs will be able to form massive stars in the future, and thus they provide a great opportunity to study the molecular cloud structure that priors the formation of massive stars and star clusters.

However, the IRDCs are typically located at distances greater than a few kiloparsecs – that is 20 times farther away than nearby, low-mass molecular clouds. This makes characterizing their physics observationally very challenging, and indeed, information about the structure of IRDC complexes and the cores inside them is still to a large degree lacking. Scientists at MPIA have been active in both using state-of-the-art observing facilities to determine physical conditions in IRDCs (e.g., Beuther et al. 2010, A&A, 518, L78; Henning et al. 2010, A&A, 518, L95; Ragan et al. 2011, ApJ, 736, 163; Ragan et al., submitted) and in developing new techniques to observe them (Kainulainen et al. 2011, A&A, 536, A48; Kainulainen & Tan, submitted).

In particular, knowledge on the relation of the IRDCs with their lower-density surroundings is virtually nonexistent. This makes it hard to examine whether the diffuse cloud material in IRDCs imposes similar external pressure to the cores within them as it does in the case of low-mass clouds.

To approach this problem, Kainulainen et al. (2011, A&A, 536, A48) and Kainulainen & Tan (submitted) recently developed a new dust extinction mapping technique that provides a very potential tool for measuring mass distributions in IRDCs. This technique refines the NIR dust extinction mapping scheme described earlier to suit IRDCs and combines the resulting data with mid-infrared (8 µm, Mir) data from the Spitzer satellite. At Mir wavelengths, the IRDCs manifest themselves as dark "shadows" against the bright Mir background radiation emitted by the Galactic plane. An example of this is shown in Fig. III.2.4, which shows a three-color (false-color) composite picture made out of 8 µm, 24 µm, and 70 µm data of the Spitzer satellite. The figure shows a



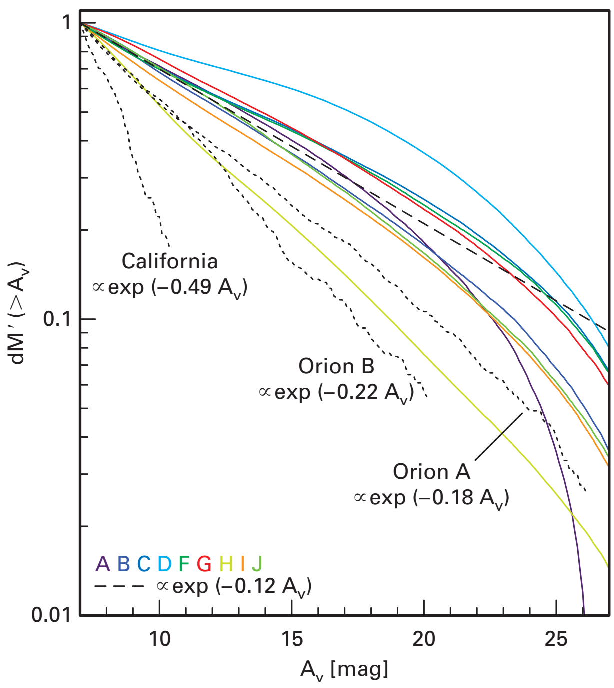
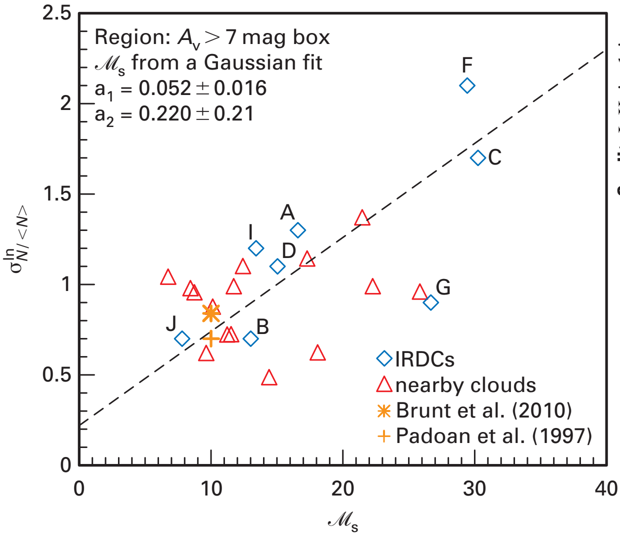


Fig. III.2.5.: *Top:* Column density PDFs of ten IRDCs (*colored lines*) and the nearby Ophiuchus star-forming cloud (*black dashed line*). The shapes of the PDFs of the IRDCs are, on average, compatible with a log-normal function (*shown with a dotted black line*). *Left:* The cumulative forms of the PDFs for the IRDCs (*colored lines*) and for three nearby molecular clouds (*black dotted lines*). The IRDCs contain somewhat more high-column density material than nearby clouds, which might reflect their location at smaller Galacto-centric radii, and hence, higher pressures.

filamentary IRDC called “The Snake”. The shadowing is caused by dust particles in the cloud that absorb the background radiation. From the amount of this absorption it is possible to estimate the mass of intervening dust, and hence, the mass distribution of the cloud.

Kainulainen & Tan (submitted) presented a scheme for combining these two types of data, NIR extinction mapping with background stars and MIR extinction mapping with surface brightness data, into mass distribution data with unprecedented high sensitivity and spatial resolution. The bottom panels of Figure III.2.4 show as an example the mass distribution map derived for “The Snake”. The data reaches the resolution of 2″, which at the distance of “The Snake” corresponds to about 0.04 Pc.

The high-dynamic-range data resulting from the new technique makes it possible not only to examine the column density PDFs in potential high-mass star-forming sites, but also to examine the PDFs of molecular clouds over a greatly wider dynamic range than the data discussed in the context of low-mass clouds (see Fig. II.2.2). Figure III.2.5 shows the column density PDFs of 10 IRDCs and that of Ophiuchus, which is a typical nearby star-forming cloud. The PDFs of IRDCs are quite similar to that of Ophiuchus (they extend to higher column densities because the dynamic range of their data is wider). This, first of all, suggests that star-formation may have already started in the IRDCs. Indeed, some of the IRDCs included in Fig. III.2.5 show some typical star-forming signs in the near-and mid-infrared, such as bubbles and reflection nebulae. However, finding out exactly how many young stars are currently forming in



Credit: J. Kainulainen

Fig. III.2.6.: Relation between the non-thermal sonic Mach number ($\mathcal{M}_s$) and the standard deviation of the column density PDF in IRDCs (*blue diamonds*) and in nearby molecular clouds (*red diamonds*). The sonic Mach number is a measure of turbulent energy in the clouds and the standard deviation of column density a measure of the magnitude of density fluctuations in it. The correlation coefficient between these two parameters describes how efficiently turbulence is inducing density fluctuations in the cloud.

the IRDCs is difficult because of their distance. It would be possible to build a census of low-mass star formation in IRDCs using X-ray observations, and MPIA scientists are involved in programs aiming at this.

Figure III.2.5 (*bottom panel*) shows the cumulative PDFs for the same IRDCs. The panel also shows cumulative PDFs of three nearby clouds: Orion A, Orion B, and the California cloud. The figure shows that IRDCs contain a relatively high amount of high-column density material, even more than the most active nearby clouds (Orion A). This may indicate that also star-forming rates in the IRDCs will be significantly higher than in nearby clouds.

The similarity of the PDFs of IRDCs with star-forming low-mass clouds suggests that the pressure-confined structures that were earlier hypothesized to be a pre-requisite for star formation have already formed in IRDCs. If so, it would indeed appear that the requirement for pressure-confined structures can form a paradigm that covers the entire mass-spectrum of star formation. However, confirming this requires further studies of the kinematic structure in IRDCs that could connect pressure to the shapes of the column density PDFs. These studies will become possible once the combined NIR + MIR mass distribution mapping technique will be applied to a large set of IRDCs.

Another interesting application of the high-dynamic-range column density data is using them to determine the total column density variance in molecular clouds. As described earlier, the density fluctuations in molecular clouds are induced by the turbulent motions in the clouds. The magnitude of these fluctuations, or in other words the total density variance, $\sigma(\varrho)$, is expected to depend on the total turbulent energy: $\mathcal{M}_s = b \times \sigma(\varrho)$. In this relation, $\mathcal{M}_s$ stands for the non-thermal sonic Mach number, which is a measure of the non-thermal kinetic (assumably, turbulent) energy in the cloud. The coefficient b is a constant that describes the strength of the coupling of the two parameters. The relation is particularly important, because the star formation theories that use the density PDF as a measure of density statistics use this to scale the density fluctuations based on the turbulent energy content in the cloud.

Figure III.2.6 shows tentatively the first direct measurement of the $\mathcal{M}_s = b \times \sigma(\varrho)$ relation in molecular clouds, performed by Kainulainen & Tan (submitted). The total density variance for the plot was measured using the high-dynamic-range dust extinction maps. The result indicates the correlation coefficient $b = 0.23$ ($3-\sigma$ interval [0.02, 0.81]). While the detection is tentative, the work demonstrates the feasibility of the technique to probe the relation when applied for a larger sample of IRDCs.

In the future: improving the link between the observations and numerical modeling

The dust extinction mapping techniques developed and used by scientists in MPIA offer highly-capable observational tools for constraining current models of star formation through accurate measurements of the mass distribution in molecular clouds. The structural characteristics derived from those data can be connected to predictions given by numerical simulations, and from therein, they can constrain the physics of the molecular cloud evolution. The current times are particularly interesting in this respect, because the state-of-the-art simulations are now starting to reach the level in which they can include all physical processes that are believed to play a role in shaping the ISM. Consequently, it will be of great interest and urgency to the community to link these simulations with observational data in a physically meaningful way. The particular questions to consider under this topic are: What structural parameters are the most meaningful probes of the underlying physical processes? What are the requirements of different observational techniques when connecting them with simulations? What is the framework, or a set of practices, that can be commonly used in transforming simulated structural parameters to an observational plane? Establishing this framework is the first step in the work required to take the advantage of the most recent numerical and observational studies of the ISM structure.

In the context of the paradigm of pressure confinement in molecular clouds, an impending question is whether the external pressure imposed to cloud structures results from turbulent pressure in the diffuse medium, or from gravitation-induced global contraction of the cloud. This question is not trivial to approach, because it is not clear how to observationally distinguish turbulent motions from global collapsing motions. Again, close interaction between numerical and observational communities are needed to develop tools that can approach the question.

Given the above considerations, one important near-future goal of the MPIA scientists working on the ISM structure is to improve the interfacing between the observational work done at MPIA and the work of key numerical communities. This is being done by building and reinforcing collaborations with research groups performing numerical simulations and through projects that specifically not only provide predictions for various physical parameters, but in fact make a direct connection between those parameters and observed quantities. Such work, together with the recent advances in the numerical and observational domains, can open a new era in our understanding of what controls star formation in the ISM.

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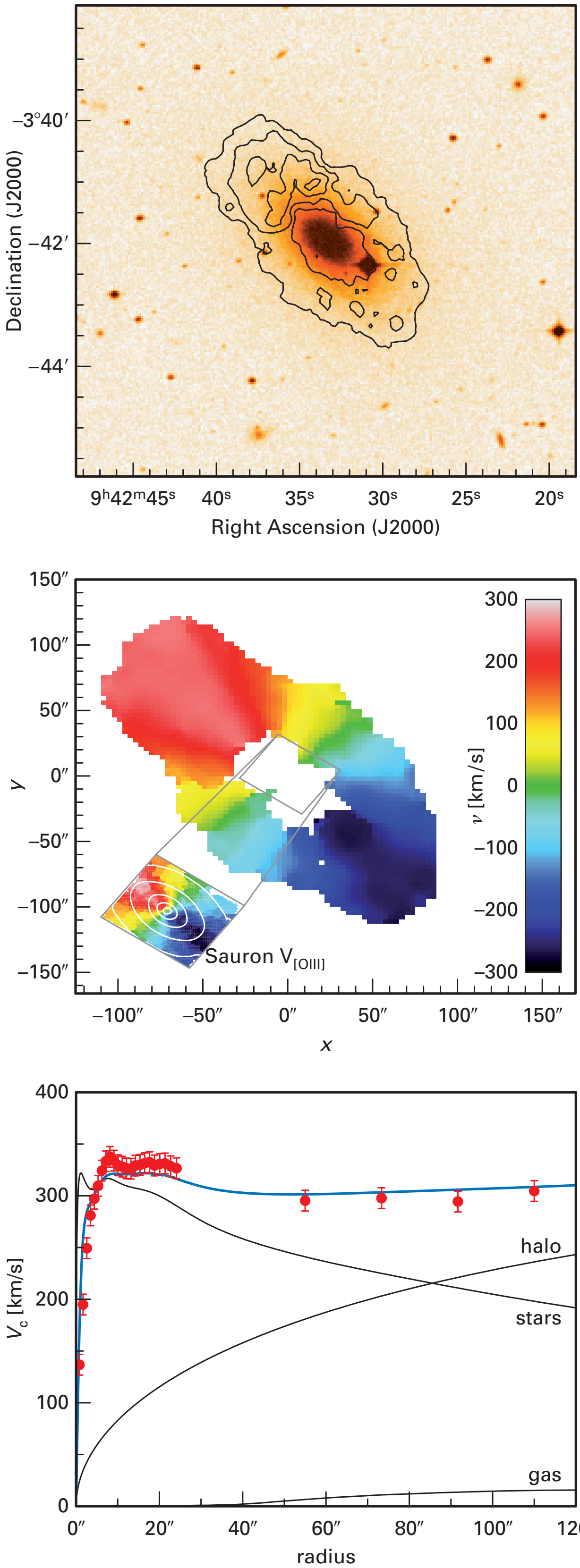
III.3 Dynamics of Galaxies: inferring their mass distribution and formation history

What is the distribution of luminous and dark matter in galaxies? How much of the formation history of galaxies has been preserved in their internal dynamical structure? Is the mass of a central black hole correlated with the mass of the host galaxy? Is the concordance cosmological model in agreement with these findings on the scales of galaxies? These key questions regarding galaxy formation in a cosmological context can be answered by studying the dynamics of galaxies. Here we present our research in this area.

Kinematic tracers

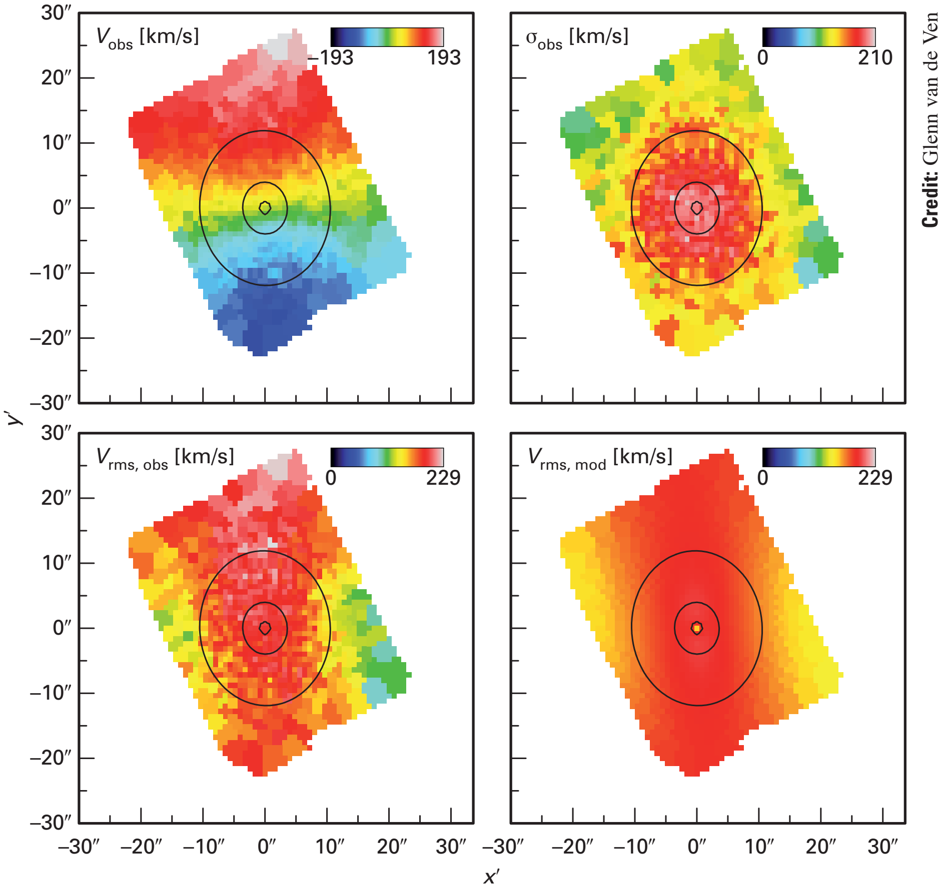
The motion or kinematics of astronomical objects is sensitive to the underlying gravitational potential, which is related, through Poisson's equation, to the density of all matter, including any possible dark components. Consider, for example, gas moving in a circular orbit at radius R in the equatorial plane of a galaxy. The mass of the galaxy enclosed within this radius $M(<R)$ determines the circular velocity $V_c(R)$ of the gas, because $G\,M(<R)/R = V_c^2$, with G Newton's constant of gravity. This means that if we can measure the gas velocity over a range of radii, we can infer the distribution of the galaxy's *total* mass, i.e., including any possible contribution from unseen components.

This is illustrated in Fig. III.3.1 for the elliptical galaxy NGC 2974. The top panel shows the projected stellar distribution, while the middle panel shows the velocity field of gas in the outer and inner parts. Red/blue indicates gas moving away/toward us along our line-of-sight, while green indicates gas that is moving in the plane of the sky. Taking out these projection effects, the red circles with error bars in the bottom panel show the



Credit: Weijmans, Krajnović, van de Ven

Fig. III.3.1: Dark matter in the elliptical galaxy NGC 2974. *Top:* Digital Sky Survey optical image showing the projected stellar distribution. *Middle:* Gas velocity map of the outer parts via atomic hydrogen HI gas obtained with the VLA radio-interferometer, and of the inner parts via ionized [OIII] gas obtained with the SAURON integral-field spectrograph. Red/blue indicates gas moving away/toward along our line-of-sight, while green indicates gas that is moving in the plane of the sky. *Bottom:* The resulting circular velocity curve of red circles with error bars clearly shows that the gas and stars alone cannot explain the corresponding total mass distribution. Adding a dark matter halo which is consistent with cosmological simulations can explain the observations as indicated by the upper black solid line. (Extracted from Weijmans, Krajnović, van de Ven et al. 2008, MNRAS, 383, 1343).



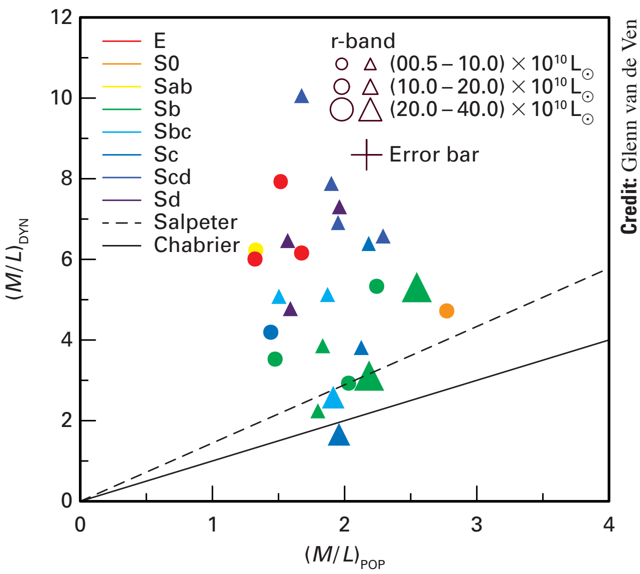


Fig. III.3.2: Dark matter content in nearby galaxies. *Top:* Oblate axisymmetric dynamical model of NGC 488. Maps of the observed line-of-sight mean velocity V_{obs} and velocity dispersion σ_{obs} are combined into the second velocity moment $V_{RMS} = \sqrt{V^2 + \sigma^2}$, which is then fitted by a solution of the Jeans equations based on the de-projected stellar light distribution multiplied with a constant mass-to-light ratio $(M/L)_{DYN}$. *Right:* The resulting total mass-to-light ratios $(M/L)_{DYN}$ are compared with stellar mass-to-light ratio $(M/L)_{POP}$ estimated based on fitting stellar population models to multi-band photometry. The $(M/L)_{DYN}$ for the circles/triangles are based on Sauron/Califa stellar kinematics. The coloring and symbol size represent galaxy type and luminosity as indicated in the legend. The dashed line indicates the increase in $(M/L)_{POP}$ when going from a Chabrier to Salpeter initial mass function, reflecting the effect of increasing the relative fraction of low-mass stars.

circular velocity of the gas as function of radius from the center of the galaxy, tracing the total mass distribution. The contribution of the gas to the total mass distribution as indicated by the lower curve is minimal. As can be readily seen from the first panel, the distribution of the stars drops with radius, so that – in the framework of Newtonian dynamics – we need a dark matter halo to explain why the observed circular velocity curve remains flat.

Inferring the total mass distribution directly from the observed mean velocity only works for tracers on circular orbits, like cold gas. Cold gas can be detected through CO and HI emission at radio wavelengths, but (1) is typically not present at all radii in galaxies and sometimes not at all, (2) settles in a plane (equatorial and/or polar) and, hence, is insensitive to the mass distribution perpendicular to it, and (3) is dissipative and, therefore, easily disturbed by perturbations in the plane from e.g. a bar or spiral arm. Stars, on the other hand, are present in all galaxy types, distributed in all three dimensions, and as they are collision-less much less sensitive to perturbations. The kinematics of stars are now routinely measured: along the line of sight via the Doppler shifts in absorption features in spectra, and in the sky-plane via the proper motion of stars that are close enough.

Stars, however, are not cold tracers as they generally move on orbits that are neither circular nor confined to a single plane. This means that in order to recover the mass distribution we need to know their velocity dispersion in addition to their mean velocity, i.e., their random motion as well as their ordered motion. Whereas the ordered motion is always around the short or long axis, the random motion can be different in all three directions, which is also referred to as velocity anisotropy. Ordered motion around the intermediate axis is unstable, but in a triaxial system a mix of ordered motion around short and long axis is possible. Moreover, we need to know the ordered and random motion throughout the galaxy to recover the intrinsic 3D mass distribution.

Unfortunately, except for the Milky Way (see below "Dynamics in the Solar Neighborhood"), we observe every galaxy in projection, and except for the nearest stellar systems (see below "Lighting up the dark in the Local Group"), we only have access to the line-of-sight stellar kinematics. This means the recovery of the mass distribution is not only degenerate with the 3D shape but also with the velocity anisotropy. The mass-shape degeneracy can be reduced, or even be broken, by constraints on the symmetry and/or viewing direction of the galaxy. For example, the case that the stellar rotation and photometry are aligned is consistent with oblate axisymmetry, and moreover, if we can infer the inclination from the presence of a dust disk, the 3D oblate shape is well constrained. The mass-anisotropy degeneracy can be reduced by observing moments of the line-of-sight velocity distribution (LOSVD) beyond the mean velocity V and velocity dispersion σ like the skewness and kurtosis. In practice, we use the higher-order moments of a Gauss-Hermite distribution (h_3, h_4, …) because they are less sensitive to the difficult-to-measure wings of the LOSVD.

It is evident that to reliably infer the total mass distribution, one needs high-quality imaging and kinematics fitted with sophisticated dynamical models. We are in particular using integral-field spectrographs – delivering spectra in two dimensions across galaxies – to obtain maps of stellar and gas kinematics, as shown in the Figures III.3.1 and III.3.2. At the same time, we are developing dynamical modeling tools that allow us to infer both the 3D mass distribution as well as the internal dynamical structure of galaxies. In what follows, we give a brief description of the results obtained so far on external galaxies, the Milky Way, and supermassive black holes in the centers of galaxies.

Dark matter in nearby galaxies

One can infer the fraction of dark matter in nearby galaxies by comparing the total mass-to-light ratio $(M/L)_{\mathrm{DYN}}$, derived through detailed dynamical modeling of the galaxy under study, to the total baryonic mass-to-light ratio $(M/L)_{\mathrm{BAR}}$, as derived from the properties of the stellar populations and gas in it.

To construct a dynamical model of a galaxy, we start by expanding its surface brightness image into a sum of two-dimensional Gaussians. In this way, seeing effects are easily taking into account and the de-projection for a given viewing direction – the inclination in the case of axisymmetry – is analytical. Another advantage is that, after multiplying each luminous Gaussian with a mass-to-light ratio, the resulting intrinsic mass density yields the gravitational potential after a straightforward single numerical integral. Whereas the contribution of a dark matter halo to the gravitational potential can be achieved by including additional Gaussians, the (preliminary) results shown in Fig. III.3.2 are under the assumption that mass follows light. In this case, each luminous Gaussian is multiplied with the same mass-to-light ratio $(M/L)_{\mathrm{DYN}}$ – still allowing for a constant dark matter fraction – to arrive at the total gravitational potential. Even though a central black hole is not resolved here (but see below "Super-massive black holes"), we do add a central round Gaussian with mass predicted from the (cor) relation between black-hole mass and host galaxy velocity dispersion.

Next, we use a solution of the Jeans equations in axisymmetric geometry to turn the multi-Gaussian luminosity density and total gravitational potential into a prediction for the line-of-sight second velocity moment $V_{\mathrm{RMS}} = \sqrt{V^2 + \sigma^2}$. As shown in the top panel of Fig. III.3.2 for the galaxy NGC 488, combining the observed line-of-sight mean velocity V_{obs} and velocity dispersion σ_{obs} yields the observed second velocity moment $V_{\mathrm{RMS,\,obs}}$ which can be compared with the predicted $V_{\mathrm{RMS,\,mod}}$ to infer the best-fit model parameters: inclination, velocity anisotropy in the meridional plane, and total mass-to-light ratio.

The bottom panel of Fig. III.3.2 shows the total mass-to-light ratio $(M/L)_{\mathrm{DYN}}$ for a range of galaxy types from spheroid-dominated ellipticals (*red*) through disk-dominated spirals (*purple*), based on fitting stellar kinematic maps obtained with either the SAURON (*triangles*) or PPAK (*circles*) integral-field unit – the latter as part of the CALIFA survey (Calar Alto Legacy Integral Field Area survey: http://www.caha.es/CALIFA/) to obtain integral-field spectroscopic data of 600 nearby galaxies. The horizontal axis shows the mass-to-light ratio of the stars $(M/L)_{\mathrm{POP}}$, based on fitting stellar population models to multi-band photometry of each galaxy, assuming a Chabrier initial mass function (IMF). The notable scat-

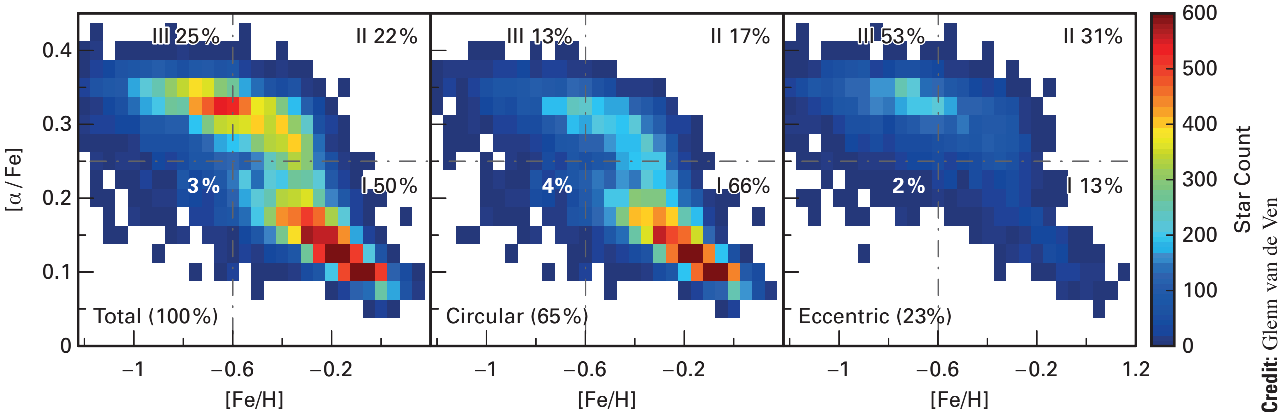


Fig. III.3.3: The number density of SDSS/SEGUE G-dwarf stars in the Solar Neighborhood as function of their [α/Fe] abundance and [Fe/H] metallicity. *Left:* The number density of all G dwarfs shows a clear bi-modality that naturally inspires a separation into α-young stars and α-old stars. Since all six phase-space coordinates are measured, the orbits of all stars can be computed in a Milky Way gravitational potential model. *Middle:* Nearly all of the α-young stars are on near-circular orbits as expected for thin-disk stars, but also a significant fraction of the α-old stars, consistent with outward radial migration. *Right:* The remaining α-old stars on eccentric orbits, including nearly all old metal-poor stars, are difficult to explain with radial migration alone, but might have formed through early-on gas-rich mergers.

ter above the diagonal solid one-to-one line is indicative of a significant dark matter fraction in the inner parts of the explored sample of galaxies. Combining the stars and gas to obtain $(M/L)_{\rm BAR}$ can bring the spiral galaxies up to 20 % closer to the diagonal line, and adopting a Salpeter IMF as more appropriate for elliptical galaxies increases their $(M/L)_{\rm POP}$ as indicated by the dashed line. Finally, we are improving the dynamical model fits by including a dark matter halo, but several galaxies will remain with $(M/L)_{\rm DYN} > (M/L)_{\rm BAR}$. Hence, significant amounts of dark matter seem to be present in the inner parts of galaxies, unless their distribution of stars is dominated by either dwarf stars (bottom-heavy IMF) and/or dark remnants (top-heavy IMF).

Dynamics in the Solar Neighborhood

In contrast to the study of nearby galaxies, the stars in the Milky Way are resolved; thus we can estimate their distances in addition to their sky positions, and we can measure their proper motions in the plane of the sky in addition to their line-of-sight velocities – often confusingly called radial velocities. This means we have access to all six phase space coordinates for at least a subset of the stars. For example, we use G-type dwarf stars from the Sloan Extension for Galactic Understanding and Exploration (SEGUE DR7) survey, leading to a sample of 13000 stellar tracers with galactocentric radius $7 < R < 9$ kpc and height above the Galactic plane $0.5 < |z| < 2.5$ kpc. Taking into account the selection of spectroscopically-targeted stars from the color-selected photometric sample, the left panel of Fig. III.3.3 shows the number density of G dwarfs as function of their [α/Fe] abundance – a proxy for age – and [Fe/H] metallicity.

Given the stars' current position and space motion, we numerically integrate their orbits in a gravitational potential $\Phi(R, z)$ of the Milky Way that includes a disk, bulge and dark matter halo. As a measure of the orbital eccentricity, we compute L_z/L_c the ratio of the conserved z-component of the orbital angular momentum to the maximum angular momentum when the orbit is circular. Even if at their birth radii the stars move on circular orbits with $L_z/L_c = 1$, the current distribution in L_z/L_c at the Solar Neighborhood is expected to extend toward values below unity, both because of stars scattering to more eccentric orbits, as well as due to measurement errors, mainly in their distance and proper motions. We choose $L_z/L_c > 0.85$ for stars being on (near-)circular orbits, and $L_z/L_c < 0.80$ for stars being on eccentric orbits, although the results are robust against the precise limits adopted.

The middle panel of Fig. III.3.3 shows that nearly all of the α-young stars are on circular orbits as expected for thin-disk stars, but a significant fraction of the α-old stars also follow circular orbits. The latter is consistent with radial migration in which stars, due to interaction at the co-rotation radius of non-axisymmetric (transient) structures such as spiral arms and bars, are efficiently moved in radius away from their birth radii while remaining on near-circular orbits. Indeed, other properties of the stars on circular orbits, such as the vertical scale height, the average rotational velocity and vertical velocity dispersion, show a smooth change with [α/Fe] as expected from in-situ formation of the thick disk through radial migration.

On the other hand, the α-old stars on eccentric orbits, including nearly all old metal-poor stars, are difficult to explain with radial migration alone. Their average properties show no significant trends with neither [α/Fe] nor [Fe/H], and are very different from the α-old stars on near-circular orbits: going from stars on near-circular to those on eccentric orbits, the vertical scale height nearly doubles, and around [Fe/H] = –0.6 the average rotational velocity halves while the vertical velocity dispersion doubles. These differences might, however, be naturally explained if the stars on eccentric orbits formed through a gas-rich merger at high redshift. It is expected that the disk from which the stars form is not smooth and thin, but clumpy with already a significant dispersion. Together with further blurring over the long time since the merger, it might well be that if any correlation with [α/Fe] nor [Fe/H] existed, it is washed out by now. Even more so, an early-on merger origin from an already hotter disk might help explain the apparent jump between the average orbital properties of G dwarfs on near-circular and eccentric orbits.

Aside from understanding the origin of the Milky Way disk(s), we are also using these G dwarfs as kinematic tracers to infer the amount of dark matter in the Solar Neighborhood, which in turn is a crucial ingredient for experiments designed to detect dark matter particles. This requires a precision determination of the local gravitational potential $\Phi(R, z)$, yielding the total mass density from which the accurately measured luminous density is subtracted to recover the dark matter density. The simplest way is to solve the vertical Jeans equation $\mathrm{d}\,(\nu_z\sigma^2_z)\,/\,\mathrm{d}z = -\nu_z\ \mathrm{d}\Phi\,(R_0, z)\,/\,\mathrm{d}z$ for a measured vertical density ν_z and vertical velocity dispersion σ_z for a tracer (sub)population around the Solar radius R_0.

However, after carefully measuring ν_z and σ_z for sub-samples of G dwarfs with similar [α/Fe] and [Fe/H], we find that the best-fit vertical Jeans solutions do not yield a consistent underlying Galactic potential; the α-young stars require a significant local dark matter density, while the α-old can be fitted without dark matter. We expect that this is, at least partly, because the underlying assumption that vertical and radial motions can be decoupled breaks down; indeed, whereas this assumption requires that the velocity cross term $<\nu_R\, \nu_z>$ vanishes, initial challenging measurements show that it is non-zero and varying with height with an indication that the variation is stronger with increasing [α / Fe].

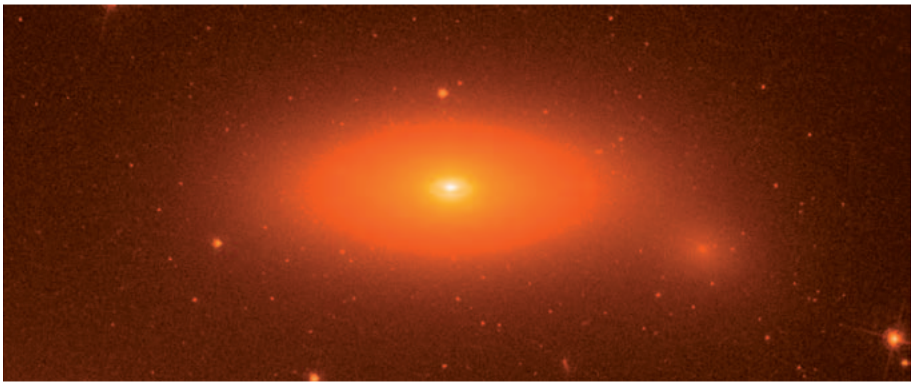
To overcome this assumption on the velocity anisotropy, we are looking into solutions of the axisymmetric Jeans equations along curvilinear coordinates that naturally allow this cross term to vary with height. We also aim to fit Schwarzschild models that do not make any assumption about the velocity anisotropy by numerically integrating in an arbitrary gravitational potential a representative set of orbits and weighting them such that observed stellar positions and motions are fitted simultaneously; the weighted orbital kinematics yield the velocity anisotropy.

Super-massive black holes

In the last two decades, observational evidence has mounted that Supermassive Black Holes (SMBH), defined as black holes with mass, $M_\bullet$, above $10^6\,\mathrm{M}_\odot$, lurk at the centres of most, if not all, massive galaxies. Measuring $M_\bullet$ *directly* is difficult and, with the current observational means, usually achievable only in nearby ($d > \sim 100$ Mpc) galaxies. It requires spectroscopic data, typically with sub-arcsecond angular resolution, as well as careful dynamical modelling of the stars (or gas) surrounding the SMBH. Yet, the number of galaxies with directly measured $M_\bullet$ has grown considerably, reaching ~ 70 as of 2012.

From this sample, it was found that the $M_\bullet$ are suprisingly tightly correlated with several of their host galaxy (bulge) properties, most prominently the stellar velocity dispersion, σ, and luminosity, L. A SMBH comprises a small fraction (on average approximately 1/500) of its host mass, and accordingly wields significant gravitational influence only in a tiny region of its host. Hence, the correlations, also termed "Black Hole scaling relations", are not explained trivially. Instead, they are thought to reflect a co-evolution of SMBHs and their host galaxies, with the responsible astrophysical mechanisms currently being subject of investigation. Apart from their significance towards understanding the formation of galaxies, as well as the origin and growth of SMBHs, the scaling relations are nowadays widely used to determine the $M_\bullet$ distribution and space density, including evolution on cosmological timescales. Here, the empirical scaling relations serve to predict $M_\bullet$ in a large number of galaxies, or in galaxies too distant for a direct measurement. Moreover, secondary (indirect) $M_\bullet$ estimators, such as reverberation mapping (for active galaxies) and the broadline-width method (quasars), are calibrated by means of the locally-defined scaling relations.

Given the importance of the SMBH scaling relations in current astrophysics, it is worth noting that their characterisation is far from secure. The uncertainties pertain, amongst others, to the universality with respect to host morphology, the validity range and functional form at the extreme mass ends, to consistency between scaling relations, as well as the precision of and especially systematic errors in the measured $M_\bullet$ and host galaxy properties. Tackling the last of these mentioned, we currently work with a new high-resolution, deep near-infrared data set, obtained by the WIRCam imager on the Canada-France-Hawaii Telescope and designed to improve the determination of bulge luminosity, L_{bul}, of SMBH host galaxies with directly measured $M_\bullet$. Near-infrared luminosity is of special interest as it serves as a proxy for stellar mass, and is hardly affected by the presence of dust. We use these superior data to model bulges by careful and comprehensive image decomposition. Simultaneously, we establish the correlation of $M_\bullet$ with total host luminosity, L_{tot}. Our results imply that the $M_\bullet - L_{\mathrm{bul}}$ correlation



Credit: Glenn van de Ven

Fig. III.3.4: Hubble Space Telescope image of the compact lenticular galaxy NGC 1277, the host of an "übermassive" black hole. The image size is 19 × 8 kpc. The galaxy has a half-light radius of 1 kpc, is strongly flattened, and is disky. North is up and East is to the left.

power-law index is decidedly below unity, in contrast to early (and widely adopted) studies. We find it likely to be not as "fundamental" as previously thought, while L_{tot} poses an equivalently strong predictor of $M_{\bullet}$.

Our group also is strongly involved in expanding our knowledge of the SMBH scaling relation with respect to the highest SMBH masses. This part of the scaling relations is of special interest not only because it is hitherto sparsely sampled. There is also doubt in the scientifc community concerning the validity of the power law established for the intermediate-mass range of SMBHs. We here specifically investigate compact galaxies with unusually high velocity dispersion, and conducted a dedicated spectroscopic survey on the Hobby-Eberly Telescope in order to find such galaxies and single out objects most promising to allow the measurement of $M_{\bullet}$. We subsequently acquired integral-field spectroscopic data of the resulting sample, using PPAK on the Calar Alto 3.5 m telescope. We were able to detect a SMBH with a mass far exceeding the prediction of current scaling relations, constituting ~14 % (instead of ~0.2 %) of the host (bulge) mass. This peculiar galaxy is shown in Fig. III.3.4. Its "übermassive" SMBH may be interpreted as a statistical outlier of the currently adopted scaling relations, but nevertheless demands a corresponding formation scenario. Whether the latter is feasible within the hitherto proposed galaxy-SMBH co-evolution models is currently unclear. As a consequence, there may be more than one principal SMBH formation channel and the established scaling relations may thus not be universal.

What next? Lighting up the dark in the Local Group

For objects in the Local Group – that is our own Milky Way, sister galaxy Andromeda (M 31) and their globular clusters and dwarf galaxy satellites – we are in the very fortunate position of being able to measure photometric and spectroscopic quantities for individual stars, often to very high precision, thanks to both their proximity and the advances in modern observing techniques. These data include not only line-of-sight velocities, but motions in the plane of the sky (proper motions) and metal abundances. Having the full 3D velocity information means we can directly calculate the velocity anisotropy, and thus break the shape-mass-anisotropy degeneracy (see Fig. III.3.5). Furthermore, by studying separately the dynamics of chemically different stellar populations, we can recover the formation history of these objects.

The Hubble Space Telescope (HST) has delivered photometric and proper motion data of exceptional accuracy and also ground-based facilities provide remarkable data-sets of line-of-sight velocities and metal abundances, as well as proper motions. Large-scale surveys may lack the sensitivity of the HST but are a vital tool due to the sheer number of stars that they have observed; surveys such as Hipparcos, SDSS, and the RAdial Velocity Experiment (Rave) have provided a wealth of information over large regions of the sky, which have been used to good effect in studies of the Milky Way. For studying the smaller denizens of the Local Group, there have also been a number of focused observing efforts; for example thousands of line-of-sight velocities have been published for four of the Milky Way's classical dwarfs: Carina, Fornax, Sculptor and Sextans. And the future is bright: there are a number of surveys coming online over the next few years that will expand the data sets that are currently available. In particular, Gaia will provide distances, velocities, metallicities and even age estimates of unprecedented accuracy over the whole sky.

We must ensure we have tools in place both to analyse the existing data and to fully exploit the upcoming data. To this end, we are extending existing dynamical modeling techniques to include proper motions as well as line-of-sight velocities, and to directly fit discrete data using maximum likelihood methods. Apart from the loss of information when binning discrete data, the likelihood method can also be extended easily to incorporate further information. For example: typically, and unavoidably in case of binning, contaminants (e.g. a

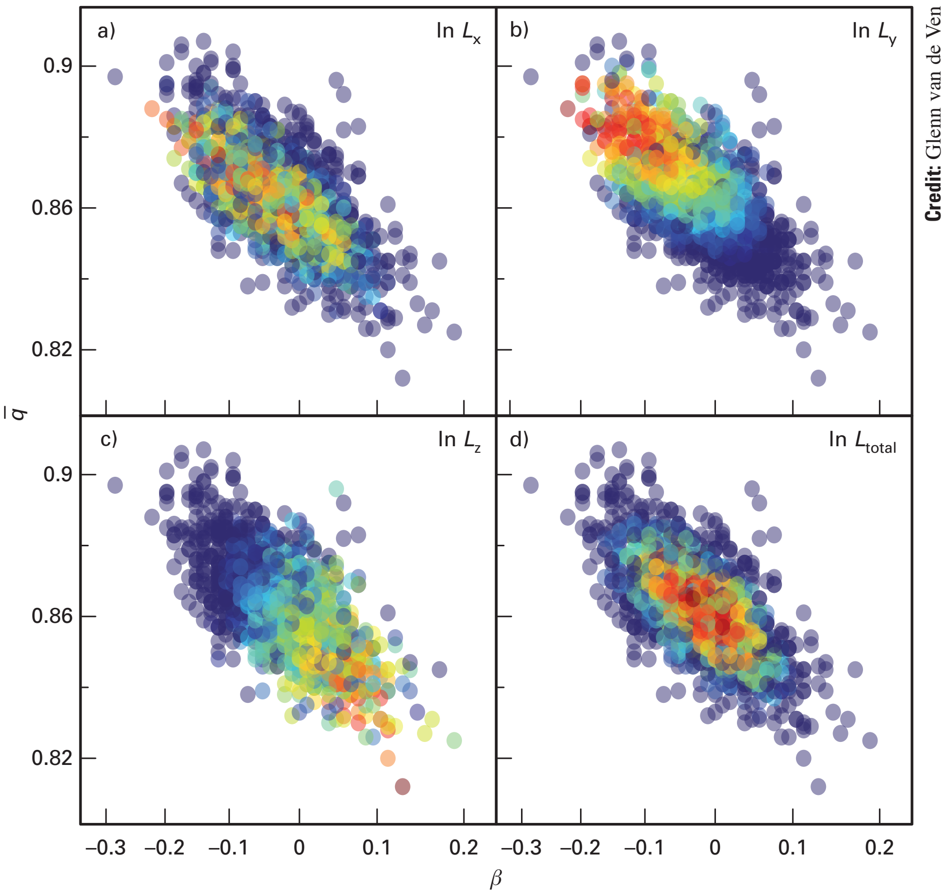


Fig. III.3.5: Posterior distribution for median projected axis ratio (shape) versus velocity anisotropy at the end of an MCMC run for ω Centauri with the points coloured according to their likelihood (red high, blue low). *a):* likelihood for *x* proper motions only, *b)* likelihood for y proper motions only, *c)* likelihood for line-of-sight velocities only, *d)* total likelihood. The degeneracy between shape and anisotropy is seen in the scatter of the points. It is clear from the first three panels that the individual velocities do not converge on the correct answer; however their combination (*as shown in panel d*) does break the degeneracy and converges nicely.

foreground or background population) are removed via a series of cuts before proceeding with the modeling; this is a tricky process – make the cuts too conservative and true members will be excised as well as the contaminants, make the cuts too generous and contaminants will still remain. A better approach is to include all stars in a model, both likely members and suspected contaminants, and allow for the presence of a contaminant population in the likelihood calculations. As our models have many parameters a simple grid search is not feasible, so we turn to Markov-Chain Monte Carlo (MCMC) methods in order to sample the large parameter space efficiently.

One prime example that highlights what we are currently able to achieve is the Galactic globular cluster ω Centauri. Located only 5 kpc from the Sun, it is large and bright and has been observed many times with many different instruments, over a long time baseline. As a result, there are line-of-sight velocities and metal abundances available for thousands of stars, and proper motions measurements available for hundreds of thousands of stars. ω Centauri is an interesting object to study as it demonstrates many qualities in common with globular clusters, such as an apparent absence of dark matter, and also many qualities in common with dwarf spheroidal galaxies, such as a complex star formation history. There is also an ongoing debate concerning the presence (or absence) of an intermediate-mass black hole (IMBH) at its center. High-quality data and sophisticated modeling techniques should enable us to finally answer some of the questions that linger over the nature of this curious object and how it has formed and evolved. The result of one MCMC model run for ω Centauri is shown in Fig. III.3.5 for two of our parameters: the median deprojected axis ratio (*q*, a proxy for shape) and velocity anisotropy (β). These plots demonstrate the shape-anisotropy degeneracy that exists, and that proper motions and line-of-sight velocities must be used together in order to break the degeneracy.

A second object to which we are applying our modeling tools is the prototypical core collapsed Galactic globular cluster M 15. A longstanding debate is whether the increase in the mass-to-light ratio (*M*/*L*) toward the center is purely due to stellar remnants that arrived at the center as a result of mass segregation, or if there is also an IMBH present. Since with our discrete likelihood fitting method we do not lose spatial information as in the case of binning, we can measure the dark central mass to higher accuracy than before. Our resulting density profile for M 15 is in excellent agreement with predictions from stellar cluster simulations, without the presence of an IMBH.

This is a promising start. However, in these preliminary models we have not yet chemical information and we have used simplified contamination models. Nevertheless, these results demonstrate that we have the machinery in place to handle both current and upcoming datasets in the Local Group, now we can work on further developing the maximum likelihood techniques and incorporating more information to truly exploit the data.

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III.4 The Interstellar Medium of Nearby Galaxies

The temperature and corresponding phase transitions of the interstellar medium (ISM) play key roles in the formation of stars, and thus galaxy evolution. Yet the heating and cooling of the ISM and associated transitions between phases are still not fundamentally understood. This section describes some of our ongoing multiwavelength work at MPIA to understand these processes and the fundamental connections between the stars and ISM of galaxies.

To understand galaxies we must first understand the physical processes that regulate their evolution: the cooling and corresponding phase transitions in the interstellar medium (ISM), the formation of stars from the cold ISM, and the return of radiant and mechanical energy from those stars, heating the ISM. Together, the structure and composition of the ISM are tracers of, and direct results from, the formation of and the feedback from stars.

The ISM is generally considered to be in three phases; ionized, atomic and, molecular, each with a range of densities and temperatures. Throughout these phases exists interstellar dust, thought to be composed mostly of carbonaceous grains and silicates, and ranging from micron-sized grains to large molecules, such as polycyclic aromatic hydrocarbons (PAHs). This ISM has a still poorly understood structure, consisting of diffuse gas, clumpy clouds, and large scale features such as spiral arms.

The heating in the ISM is dominated by young, massive stars, with large UV fluxes that ionize interstellar gas, eject photoelectrons from dust grains, and heat the same dust grains to high temperatures. These stars also have a large mechanical energy input into the ISM due to their strong winds during their lifetimes, and the supernova at the end of their lives. ISM cooling is dominated by recombination and forbidden lines within ionized regions, and far-infrared continuum and line emission (e.g. from HI and CO) in neutral gas and in the cold molecular clouds from which stars form. It is this emission that allows us to trace the ISM structure and its phases.

The processes that shape the ISM occur on varying scales; the galactic scale spiral density waves observable at both optical and infrared wavelengths, the large scale outflows driven by starbursts and supernovae, the small scale molecular clouds that form stars, and the individual HII regions and the photo-dissociation regions that surround them. While observations of individual interstellar clouds and star-forming regions within the Milky Way provide the highest spatial resolution, studying the various scales of energy and heating balance within our own Galaxy proves difficult as line-of-sight reddening in the optical and UV, uncertain distances, and background/foreground confusion lead to enormous complications.

Observations of external galaxies avoid these problems and in addition allow one to explore a significantly wider range of physical properties, such as metallicity, ISM densities, and star formation rates (SFR). In particular, nearby galaxies provide a vital bridge between in-depth, resolved studies in our Galaxy and the globally integrated measurements of distant galaxies. In nearby galaxies it is possible to explore the ways and the scales over which different stellar populations affect the surrounding ISM in different regions of galaxies (i.e. spiral arms and inter arm regions, bulge, and disk, etc.) and at different metallicities, as well as large ranges in gas and dust column densities.

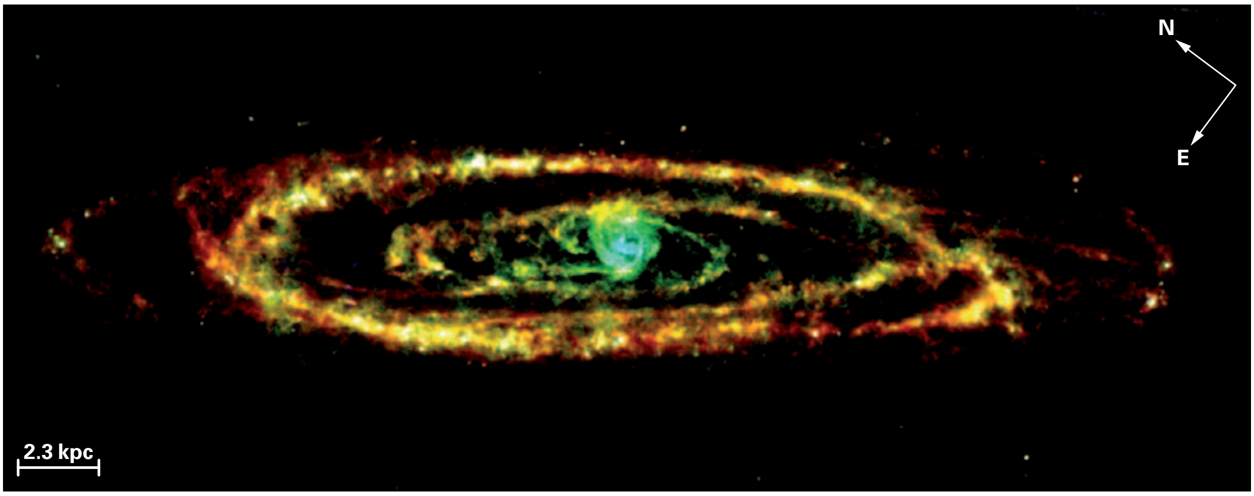
Nearby Galaxies at all Wavelengths

MPIA has conducted several multiwavelength surveys of nearby galaxies, and is part of several more through collaborations. These multiwavelength surveys enable the delineation of both the stars and multi-phase ISM in these galaxies. We detail a fraction of these below that are ongoing.

• **The Andromeda Galaxy** (Messier 31) is the nearest massive spiral galaxy to our own, and thus provides the best spatial resolution while still giving an integrated galaxy view. We have recently obtained Herschel Space Observatory images from 70 – 500 μm of Andromeda (see Fig. III.4.1) and in association with existing multiwavelength observations, this allows us to directly connect the dust with stars and all phases of gas. By including a MPIA-involved heritage Hubble survey of M 31 that resolves individual stars (Phat; Dalcanton et al., 2012) we can directly determine ISM heating input from stars to dust.

• **The Whirlpool Galaxy** (Messier 51) is an interacting grand-design spiral galaxy that is face-on ($i \sim 23°$), extremely gas rich, with a high current rate of star formation. With the *Plateau de Bure Interferometer Arcsecond Whirlpool Survey* (Paws) we have mapped ^{12}CO(1–0) in the central 11×8 kpc of M 51, detecting molecular clouds down to $\sim$40 pc scales and masses down to 10^5 $M_\odot$, typical values for Galactic GMCs. In association with an existing multiwavelength dataset, this allows us to directly connect the molecular gas clouds with dust, stars, star-formation (i.e. HII regions) and atomic (HI) gas.

• **The Sings/Kingfish/Things/Heracles sample**
MPIA is part of and has contributed to the largest multiwavelength, resolved sample of galaxies with the combination of the Infrared Sings (Spitzer; Kennicutt et al., 2003) and Kingfish (Herschel; Kennicutt et al., 2011) surveys and the HI Things (Walter et al., 2008) and Iram



Credit: Groves et al. (2012)

Fig. III.4.1: A HERSCHEL far-infrared image of the Andromeda galaxy showing 70 µm (*blue*), 100 µm (*green*), and 250 µm (*red*). The bluer colors indicate hotter dust.

CO HERACLES (Leroy et al., 2009) large surveys. Along with ancillary GALEX-, optical- and radio data these surveys provide resolved ultraviolet to radio imaging of ~50 nearby galaxies, and the ISM gas traced via HI and CO line emission and spectral maps of other optical to far-IR emission lines. These data provide the best opportunity to link resolved galaxy ISM and stellar properties with the global galaxy type and environment. In the following we highlight some of our recent findings from these projects.

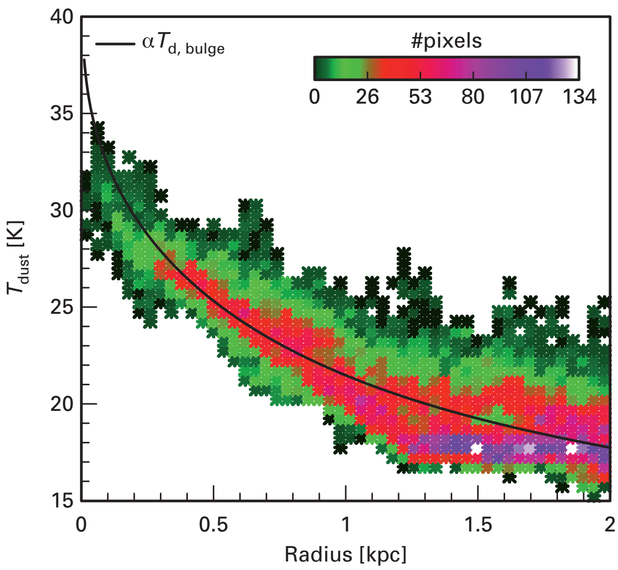
Dust heating: Andromeda's Hot Dust

The dust in the ISM of galaxies is strongly associated with the gas, with the total dust column being a function of the gas column. However, the IR emission from dust in galaxies is also dependent upon the dust temperature, which is determined by the interstellar radiation field. As dust opacity is strongly biased to the UV, massive stars tend to dominate the heating of dust. Due to this, IR emission, either alone or in association with another tracer such as Hα or UV emission, is used as a measure of the current star formation rate (SFR).

The center of Andromeda presents a difficulty in this standard paradigm of dust IR emission. As seen in Figure III.4.1, the center is particularly bright in IR, with the blue colors indicating warm (~30 K) dust. Yet high resolution imaging (e.g. from HUBBLE; Rosenfeld et al., in prep.) reveal no massive stars and no ongoing star formation. However, the heating mechanism of the dust is revealed by the steep radial profile in dust temperatures at the center, determined from simple fits to the HERSCHEL far-IR bands in each pixel with emissivity modified-blackbodies, shown in Figure III.4.2 (from Groves et al., 2012). This dust temperature distribution is overlaid with a scaled version of the expected dust temperature from heating by the diffuse radiation field arising from the old stellar population of the bulge of M 31, with the profiles showing a close match.

This match indicates that it is the bulge stars that are heating the dust, with the high density of stars in this region providing a sufficiently strong radiation field to heat the dust to warm temperatures. This is significant for two reasons; it demonstrates that warm dust emission is not always associated with young, massive stars, and that, given the very red optical spectra of the bulge, optical light, not UV, can dominate the heating of the dust. Given the "early-type" nature of Andromeda's bulge, such heating may also be occurring in other early-type galaxies that also show warm dust emission.

Fig. III.4.2: The distribution of dust temperatures within the inner 2 kpc (530″) of M 31. The colors show the number density of the ~23 pc pixels dust temperature (T_d) and distance from the center, as labeled by the color bar. Overlaid is a curve showing a scaled version of the expected dust heating given the bulge radiation field from old stars.

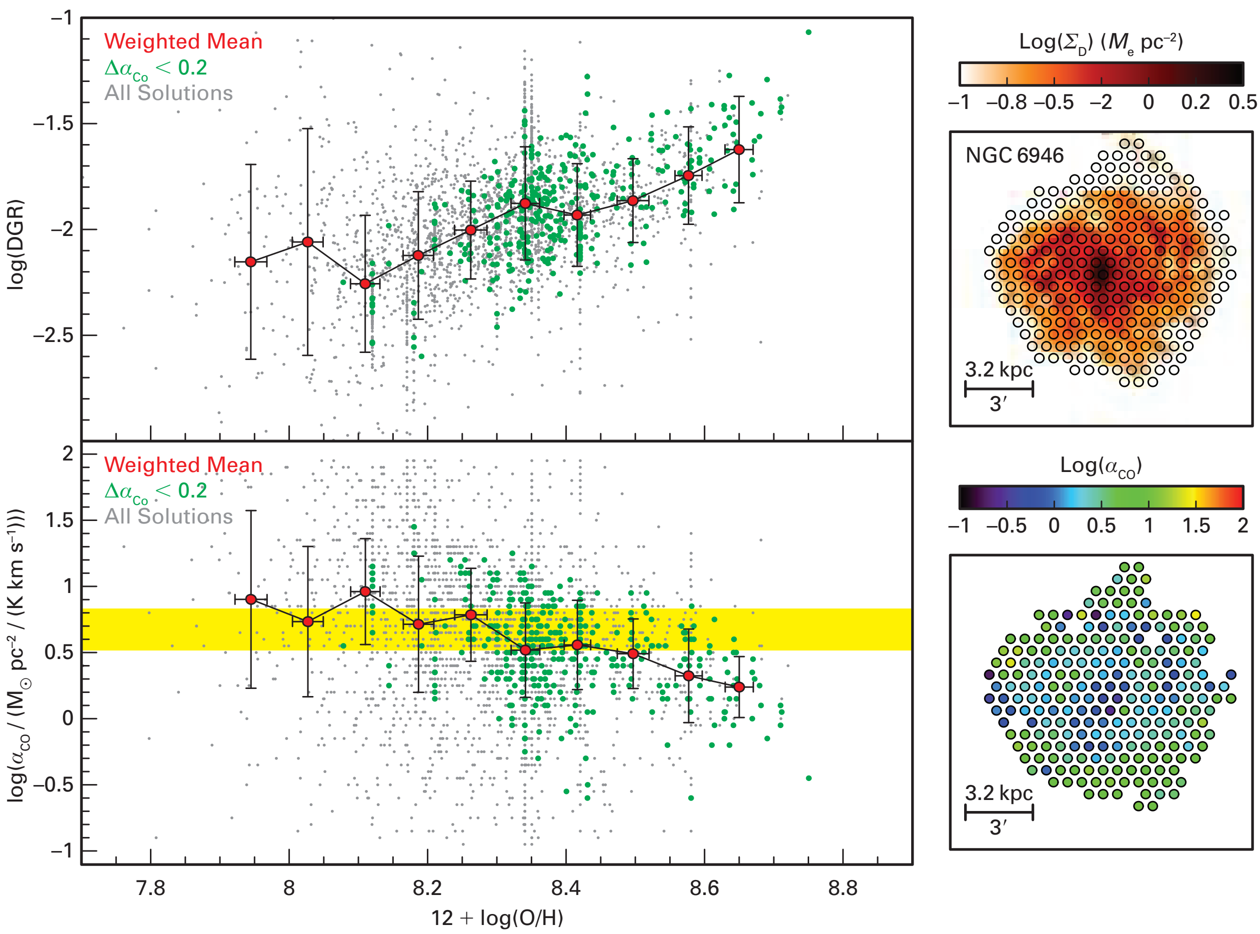


Credit: Groves et al. (2012)

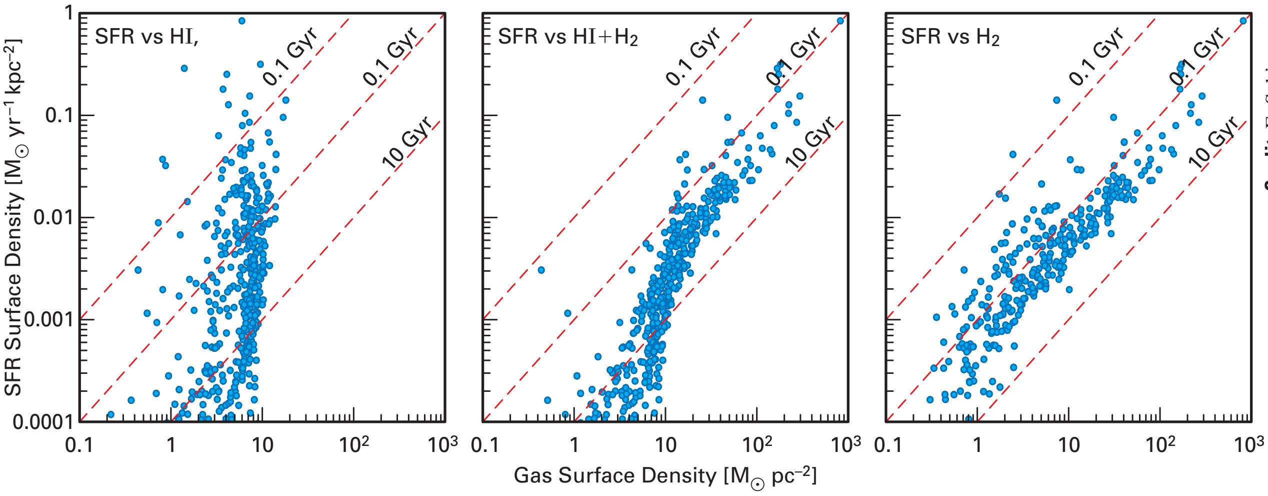
Tracing "hidden" gas: the gas to dust ratio

While tracing atomic gas is relatively simple through observations of the HI hyperfine line at 21 cm, observing cool, molecular H_2 is difficult due to its lack of a dipole moment. The standard method is to observe the CO (submm) emission lines and convert to the total H_2 through a conversion factor, α_{CO}. This factor is determined in the Galaxy using dynamical methods yet remains relatively uncertain because of possible variations due to abundance effects, or "hidden", CO-absent, molecular gas. However, as dust and gas are closely coupled, it is possible to use the total dust mass to trace the total gas mass and constrain α_{CO}. Using a technique based on Leroy et al. (2011), and data from the KINGFISH and HERACLES surveys, we constrained α_{CO} and the dust-to-gas mass ratio (DGR) on ~kpc scales across the disks of 26 galaxies (Sandstrom et al., 2012). We observe several trends in α_{CO}, based on our nearby galaxy sample. Galaxy centers frequently show low values of α_{CO}, in some cases nearly an order of magnitude below the typically assumed local Milky Way value of $\alpha_{CO} \sim 4.35\, M_\odot\, pc^{-2}$ (K km $s^{-1})^{-1}$. Using uniformly determined metallicities from H II region spectra, we find a general trend of decreasing α_{CO} with increasing metallicity, while for DGR we measure a clear, positive, linear trend with metallicity (Fig. III.4.3). However, large galaxy-to-galaxy offsets in the relationship between metallicity and α_{CO} suggest that metallicity may not be the primary driver of variations in α_{CO} in the central, higher metallicity regions of galaxies. Due to the strong radial gradients in many quantities, it is difficult to isolate which physical process is the driver of α_{CO} variations, but in general regions with intense UV fields, high star-formation rate surface densities and/or high stellar mass surface densities show low α_{CO}.

Fig. III.4.3: *Left:* Solutions for DGR (*top*) and α_{CO} (*bottom*) plotted versus oxygen abundance based on the Pilyugin & Thuan (2005) calibration. The gray points show all of the individual solutions. The green points show the highest-confidence solutions. The weighted mean and standard deviation of all of the solutions in 0.1 dex bins are shown with red symbols. The shaded yellow region shows the approximate range of α_{CO} values determined in the Milky Way. *Right:* The dust mass surface density in NGC 6946 (*top*) showing both the apertures and region over which the values were determined, and the resulting α_{CO} for the same galaxy (*bottom*), revealing significantly lower values in the central region.



Credit: E. Schinnerer



Credit: E. Schinnerer

Fig. III.4.4: The star formation relation for different types of gas: (*left*) atomic gas seen in HI, (*middle*) total neutral gas ($HI + H_2$), and (*right*) only molecular gas (H_2). We use sensitive molecular CO gas data from HERACLES and a novel technique to stack spectra that allows us to measure faint CO emission with high significance in regions dominated by atomic gas (HI). While the SFR is not correlated to HI, it does correlate with H_2 and total gas column. However, the scaling is uniform for all regimes only for H_2.

Star-Formation Relations: Connecting stars and gas

While stars form out of molecular gas – a process that is confirmed by observations of Giant Molecular Clouds in the Galaxy and supported by the strong correlation of gas and SFR in nearby galaxies (see e.g. Bigiel et al., 2008) – there has been a long standing debate of the role atomic gas has on star formation on large scales. The lack of a clear correlation of HI and SFR in the inner parts of galaxy disks offers circumstantial evidence that star formation remains coupled to the molecular, rather than the total gas even where the ISM is mostly atomic. However, the exact relationship remained largely unexplored in the HI dominated regime, until the THINGS and HERACLES surveys revealed the most sensitive view of the entire star-forming disks of nearby galaxies to date. Using the HI and CO data from these surveys we applied a novel technique to stack CO spectra and thus measure extremely faint emission (Schruba et al. 2011). Using HI velocities to shift the CO to a common velocity and then stacking and radially average, significantly increases the signal-to noise and allows to detect CO down to $\Sigma_{H_2} \sim 1\ M_0\,pc^{-2}$, or one order of magnitude deeper than previous studies. Combining the far-UV and 24 µm emission from the SINGS survey to measure the SFR, we compared the role of different phases in the ISM to star formation (Fig. III.4.4). We found that while HI and SFR are only weakly correlated, H_2 and total gas column show strong correlations with SFR. However, only the H_2–SFR relation can be parametrized by a unique (linear) function that is valid in both the H_2 and HI dominated regime. Thus, star formation in molecular clouds appears to be independent of environment (e.g., the local gas density), however, the formation of molecular gas out of the atomic gas shows systematic variations across galaxies and a strong dependence on galactic environment.

Clouds and Clumps: Tracing the molecular ISM structure in the Whirlpool galaxy.

The assembly of giant molecular clouds (GMCs) out of the diffuse interstellar medium (ISM) and subsequent onset of star formation is an active area of astrophysical research. In normal galaxies, these GMCs are often described as the basic unit of structure in the molecular ISM, with typical GMC masses of $\sim 10^4$ to $10^6\ M_\odot$ and sizes of ~ 10 to 50 pc observed. Most Galactic star formation activity appears to occur within GMCs, but our knowledge of the processes that regulate the physical and chemical properties of GMCs is far from being complete.

To date, wide-field CO observations that can resolve individual GMCs have been restricted to the Local Group, mostly surveying low mass galaxies where atomic gas dominates the interstellar medium (for a review, see Fukui & Kawamura 2010). This is a major shortcoming since massive disk galaxies dominate the mass and light budget of star-forming galaxies and host most of the star formation in the present-day universe. With PAWS we resolve this issue, exploring a massive, molecular gas dominated galaxy at high physical resolution. In Figure III.4.5, we present the map of CO integrated intensity within M 51 obtained by PAWS. For comparison, the other panels of this figure show CO integrated intensity maps of M 33 (Rosolowksy 2007) and the LMC (Wong et al 2011), after smoothing the three datasets to the same resolution and extrapolating them onto the same pixel grid. Unlike the CO emission in the low-mass galaxies, it is obvious that much of the emission in M 51 arises in

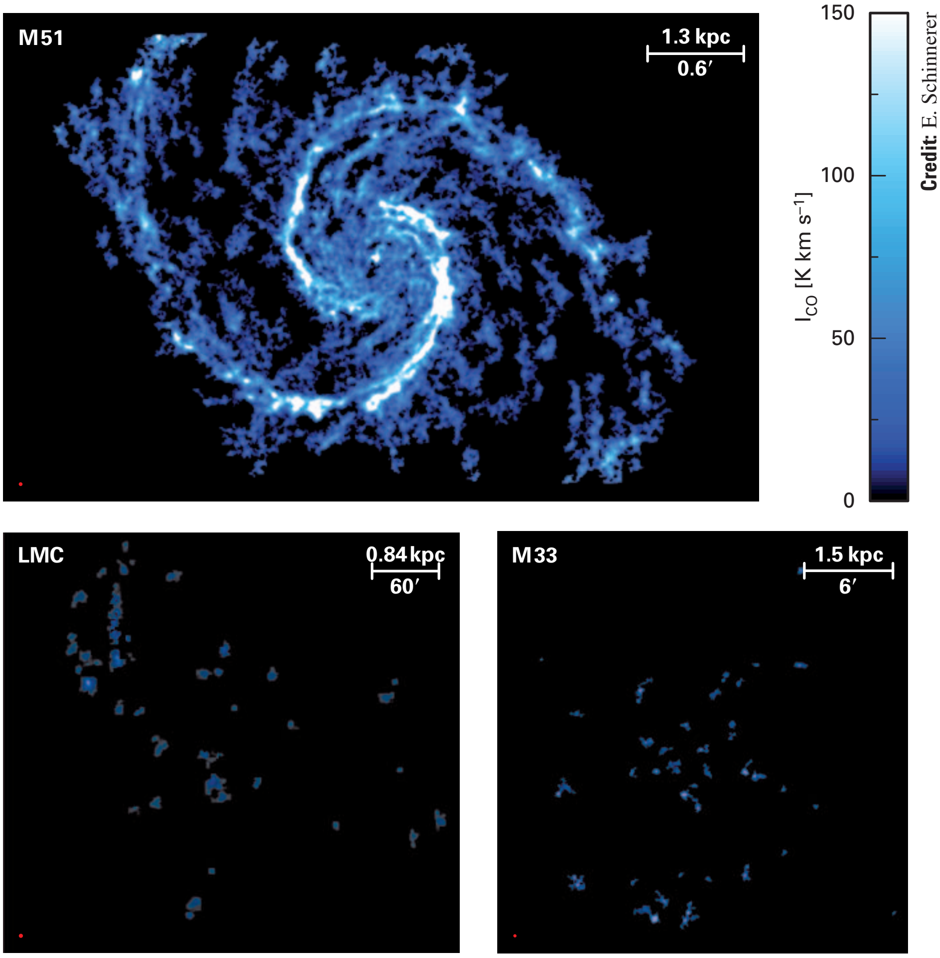


Fig. III.4.5: Maps of CO integrated intensity in M 51 (Schinnerer et al, in preparation), M 33 (Rosolowsky et al. 2007), and the LMC (Wong et al. 2011) after matching the spatial and spectral resolution of the data-cubes and interpolating them onto a pixel grid with the same physical dimensions. For all panels, the telescope beam is shown as the small red circle in the bottom left corner, and the image scale by the bar and text in the top right. The maps are presented using a square-root intensity scale with the limits of the color stretch the same to highlight the significant difference in CO brightness between M 51 and the other galaxies.

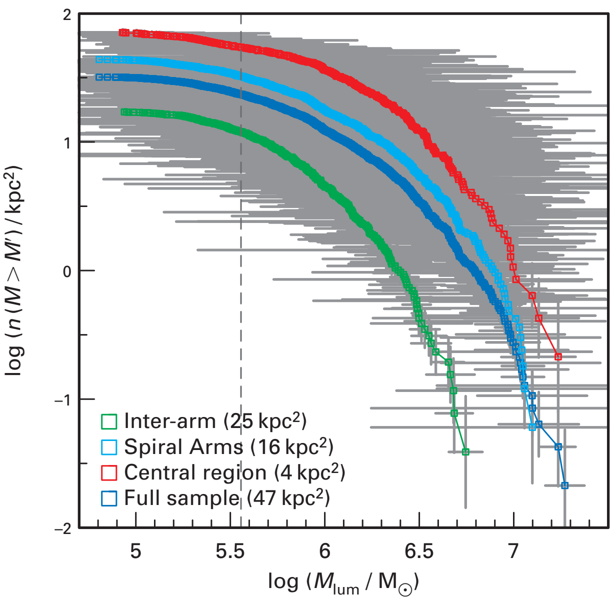
bright kiloparsec-sized structures that bear little resemblance to the discrete isolated clouds that are present in the low-mass galaxies. Bright CO emission is also clearly detected between the spiral arms, both in cloud-like structures and as thin filaments that appear to span the inter-arm region.

Assuming that CO integrated intensity is a reliable tracer of molecular gas column density, our observations indicate that regions of high gas column density develop within M 51's spiral arms and in a central region that we identify as the "molecular ring", a zone where molecular gas accumulates due to the action of opposing torques from the nuclear stellar bar and first spiral arm pattern. Gas in the inter-arm, by contrast, achieves lower maximum column densities and the probability density function (PDF) of line intensity tends towards a characteristic lognormal shape, suggesting that the gas density distribution in the inter-arm region is determined by physical processes occurring on relatively small scales. Overall, our results confirm the standard argument that lognormal PDFs in galactic disks emerge via the central limit theorem from the combined action of independent physical processes that modify the gas density distribution locally. What was less expected from numerical models is that galactic structure (i.e. M 51's stellar spiral arms and bar) clearly plays an important role in organizing the density distribution of the molecular ISM on ~50 pc scales.

Using the PAWS data and a novel finding method, we have identified over 1500 GMCs within the inner disk of M 51. This is the largest GMC catalogue that has ever been constructed for any galaxy including the Milky Way. We have studied the physical properties of GMCs located in different dynamical environments within M 51, and compared the properties of GMCs in M 51 to the GMC populations of M 33 and the LMC. Contrary to previous comparative studies that analyzed modest, observationally heterogeneous samples of GMCs (e.g. Bolatto et al 2008), we find clear evidence for environmental effects on GMC properties: clouds in M 51 are brighter, and they have higher mass surface densities and larger velocity dispersions relative to GMCs of comparable size and mass in low-mass galaxies. These trends are also observed within M 51 (Fig. III.4.6): GMCs in the spiral arms and central region of M 51 tend to have higher CO masses than GMCs located between the arms. One possible explanation for the difference in CO brightness is that the neutral ISM in the low-mass galaxies and inter-arm region has a lower dust abundance and/or more clumpy structure, enhancing the selective photodissociation of CO molecules and reducing the filling factor of CO emission on ~50 pc scales. We are currently investigating the physical processes, e.g. galactic rotation, spiral arm streaming and feedback from star formation activity, that potentially contribute to our measurement of a GMC's velocity dispersion within different M 51 environments.

ISM kinematics influence the formation of stars

Gas kinematics on the scales of Giant Molecular Clouds (GMCs) are essential for probing the framework that links the large-scale organization of interstellar gas to cloud formation and subsequent star formation. The M 51 PAWS observations permit the first such study in a galaxy outside the Local Group, in an environment which is dynamically rich and characterized by strong non-circular gas flows. To interpret these motions we combine the PAWS data with a profile of present-day spiral arm torques newly derived from the stellar mass distribution mapped with SPITZER / IRAC 3.6 μm and 4.5 μm images (Meidt et al. 2012). The observed gas motions suggest a strong response to torquing by the stellar spiral pattern, and dynamically distinct zones exhibit different GMC properties as well as distinct patterns of star formation.



Credit: E. Schinnerer

By comparing gas inflow and star formation rates throughout the disk, we assemble a view of the spatial-dependence of gas depletion times for the current gas reservoir (Fig. III.4.7). We find that the lowest azimuthally averaged star formation efficiencies (highest depletion times) coincide with zones of elevated radial gas inflow. We interpret this as the dependence of GMC stabilization on dynamical environment via the Bernoulli principle, which raises the stable cloud mass in the presence of strong spiral streaming. We find that this picture can reproduce the observed pattern of star formation efficiency where conventional sources of GMC stabilization, such as shear and turbulence, fail. High streaming motions along the spiral arm can reduce the cloud surface pressure by an order of magnitude compared to virialized clouds, with the outcome that there are fewer clouds unstable to collapse per free-fall time along particular segments of the spiral arm. Such dynamical effects contribute to the observed scatter in the standard 'cloud equilibrium' relations and star formation laws.

Magnetic fields in nearby galaxies

Understanding the role of magnetic fields in the appearance and evolution of galaxies is an important concern in modern astrophysics. Magnetic fields can significantly shape the ISM, and the pressure provided by magnetic fields and turbulent motions can be greater than the thermal pressure provided by the different gaseous phases (e.g., Tabatabaei et al. 2008). Radio synchrotron emission, and its polarization and Faraday rotation, are powerful tools in the study of the strength and structure of magnetic fields in galaxies. Polarized emission traces ordered magnetic fields, which can follow a large-scale spiral pattern in grand-design, barred and flocculent galaxies. Unpolarized emission traces random magnetic fields which are strongest in spiral arms and in central starburst regions. Our recent studies, based on the nearby late type spiral galaxy and KINGFISH target NGC 6946, show a power-law correlation between star formation rate surface density and the random magnetic field strength (Tabatabaei et al., subm). This is observational evidence of generation

Fig. III.4.6: Cumulative number surface density for M 51's Giant Molecular Clouds (GMCs) with masses greater than M', as identified within the PAWS field of view. The full sample of 1507 GMCs (*dark-blue squares*) has been divided in three main regions: central (*red*), spiral arm (*light blue*) and inter-arm regions (*green*). The three regions encompass dynamically distinct environments (see Meidt et al. 2012). The mass functions show a clear change in both the slope and density between different galactic environments. The vertical dashed line indicates the completeness limit of the catalog set ($3.6 \times 10^5\,M_\odot$). The surface area of each region over which the mass spectra is determined as labeled.

Credit: E. Schinnerer

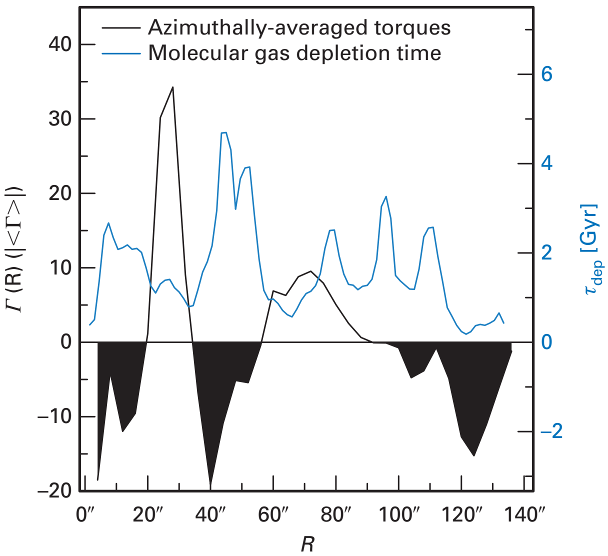


Fig. III.4.7: Azimuthally-averaged torques (*black and white*) and molecular gas depletion time (or inverse star formation efficiency; *blue*) calculated in radial bins in M 51. Each crossing from negative to positive torque corresponds to the location of the co-rotation resonance (CR) of the structure: inside CR material moves inward and outside material is 'pushed' outward. The longest gas depletion times coincide with radial inflow, which can be mapped to the largest non-circular streaming velocities along the arm.

and/or amplification of the random magnetic field by the turbulent gas motions induced by star formation. The ordered magnetic field has, however, no correlation with star formation rate in NGC 6946. The origin of the ordered magnetic field is believed to be linked to a mean field dynamo effect that depends on galactic differential rotation (Fletcher et al. 2011).

The ISM in detail: The future of nearby galaxy studies

The future of ISM studies in nearby galaxies at MPIA is very bright, with a wealth of optical, infrared and sub-mm data becoming available. Using the PPaK / PMAS instrument at Calar Alto, we have obtained integral field spectroscopy of a sample of the KINGFISH galaxies. Using these we are tracing the excitation and attenuation of the ionized ISM in the galaxies, which we can directly compare to the dust distribution from KINGFISH, and the excitation of the molecular gas from HERACLES and new HERSCHEL-SPIRE spectra currently being obtained and reduced. In the far-IR we have recently obtained HERSCHEL-PACS spectral maps of the [CII] 158 μm emission line, one of the dominant coolants of the diffuse ISM, for selected regions in M 31. Along with the resolved stars from PHAT and the high resolution dust maps from HERSCHEL, the direct input, heating and cooling of the diffuse ISM can now be determined. Finally, with ALMA now fully starting its science operation, and the NOEMA extension to the IRAM Plateau de Bure Interferometer, the molecular ISM of nearby galaxies can be observed at even higher resolution and higher sensitivity, resolving molecular clouds into individual clumps and cores down to the scales at which star formation is occurring. In addition, these new instruments will for the first time allow for the extensive study of the molecular gas composition using chemical tracers, i.e. different molecules and ions, for the dense, shocked, and ionized molecular gas in galaxies.

Eva Schinnerer, Brent Groves, Fabian Walter, Oliver Krause, Andreas Schruba, Karin Sandstrom, Annie Hughes, Dario Colombo, Sharon Meidt, Fatemeh Tabatabaei, Hendrik Linz

IV. Instrumental Developments and Projects

Here we report on further activities mainly belonging to our instrumentation projects and related technical developments. Since the number of ongoing projects is rather large, we are only presenting a selection of our current activities. Since this selection varies over the years, we encourage the reader to have also a look into other Annual Reports of MPIA.

IV.1 The Pan-STARRS1 surveys and some early results

The Pan-STARRS1 project is the first of a new generation of imaging survey telescopes of "extremely large" figure of merit and powerful data processing pipeline. Pan-STARRS stands for the *PANoramic Survey Telescope And Rapid Response System*, and its first unit out of four planned is called Pan-STARRS1 (or PS1 for short) and is located on Haleakala in Hawaii. MPIA and its other partner institutes of the MPG and elsewhere founded in 2006 the PS1 Science Consortium to support the telescope operations and conduct the PS1 surveys; and to organise the scientific work. As a major contributor, MPIA enjoys full access rights and leads several scientific areas called "key projects". In addition, the institute may offer access rights to six German scientists. We used this opportunity to strengthen our scientific ties to university colleagues. During the commissioning phase, MPIA contributed to the characterisation of the telescope performances. After almost a year of further system optimisation and partial scientific operations, the telescope and camera were deemed ready for regular survey operations, which started in April 2010.

An extremely large camera

The PS1 project features a fast, 1.8-m telescope, with an average overhead of 13 seconds between two exposures; the largest-ever built camera with 1.4-Gigapixel, 7-square degrees field of view, and sensitivity between 0.35 and 1.02 μm; and a dedicated pipeline capable of reducing the night's observations and delivering catalogues before tea time. The pipeline also produces advanced data products such as stacked images, which are the sum of all the images observed over a given sky area, and differential imaging, which in contrast one subtracts the most recent image to a template of the field, in order to easily detect variable sources, or new astronomical objects such as supernovae.

The large field of view of the camera, six times the Full Moon in diameter, and 35 times in solid angle, allows to cover the whole sky visible from Haleakala with about 4300 telescope pointings. After 1.5 years of regular survey operations, PS1 has covered a few times the sky North of DEC = –30° (3π-steradian survey) in five optical bands. This is twice the area covered by the Sloan Digital Sky Survey (SDSS), a PS1 precursor and one of most successful astronomical projects ever, over its decade of imaging operations.

The photometric calibration is on-going, either against SDSS photometry or using PS1 overlapping observations with "übercalibration". Proper motions calculated using 2MASS as the first epoch have a typical accuracy of 10 mas/yr.

In addition, shallower imaging is obtained in parallel to the CPG1 observations, at low spatial resolution.

Fig. IV.1.1: NGC 894 in gri colours, in the Medium Deep Field 01.

Credit: N. Metcalfe et al.

Credit: Morganson et al., arXiv:1109.6241

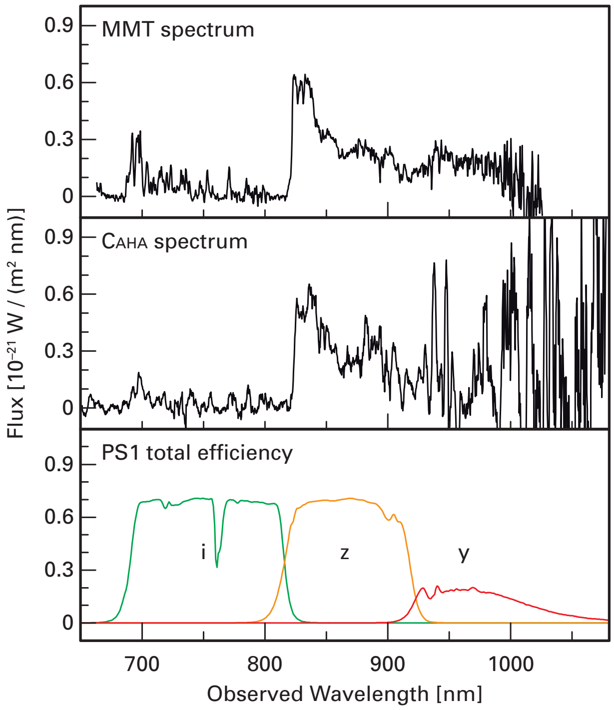


Fig. IV.1.2: The spectra of the first PS1 high-redshift quasar obtained by MMT and Calar Alto as well as the PS1 iP1, zP1, yP1 filter curves.

These data will fill the $V = 10-15$ mag gap between the HIPPARCOS photometry of bright stars, the deep photometry of PS1 and SDSS. This range is crucial for the detailed study of the closest cool stars and is only available with large uncertainties from the plate surveys.

Other surveys of interest to us are the Medium Deep Survey, which monitors daily up to four pointings, and cover 70 square degrees, and the PanPlanets survey dedicated to the search over transiting exoplanets, particularly around M-type dwarfs.

Published results cover the Solar system and near-Earth asteroids up to the most distant quasars, with a $z = 6.0$ quasar discovered at MPIA. As the first deep, wide, high-accuracy optical survey, PS1 is a unique resource for the community. Prior to its full data release expected 2015, it has established Memoranda of Understanding with several large projects with other wavelength coverage or spectral resolutions, which greatly benefit from the PS1 catalogue. High-schools in Heidelberg and world-wide have access to the images to search for asteroids, and have successfully done so.

Early Results obtained at MPIA

MPIA has concentrated its efforts in four main areas: very-low mass stars and brown dwarfs of the solar neighbourhood, exoplanets, the structure of the Milky Way, and Quasars.

Our search for cool brown dwarfs of the solar neighbourhood firstly involved cross-matching with 2MASS and selecting red y-J candidates. As SDSS before, PS1 has the right wavelength sensitivity to detect the early T-type dwarfs. Over 40 new T-type dwarfs have been discovered (Deacon et al., 2011, AJ 142, 77). A cross-match with WISE is underway. Proper motions based on 2MASS and PS1 data also revealed new brown dwarf companions to Hipparcos stars (Deacon et al., arXiv:1109.6319), providing new benchmark objects to calibrate the brown dwarf models.

We take advantage of the wide sky coverage of PS1 to study the nearby 625-Myr-old Hyades cluster. We can select cluster candidates to large cluster radii (30 pc) to study the cluster evaporation, especially close to the stellar/brown dwarf boundary (Goldman et al., submitted to A&A). We confirm previous indications of mass segregation with a larger significance and the lack of low-mass members at the cluster centre. The PS1 survey also offers an unprecedented look at the structure of our Galaxy, with deep, uniform optical data in five bands covering the whole Galactic plane in addition to the Northern Galactic Cap. The MPIA leads the PS1 science collaboration's study of the Galaxy. Our research in this area includes: a search for new dwarf galaxies, the characterisation of the structure of the Monoceros stream, and mapping the Galaxy' dust.

Regarding our quasar work, we first use the deep z– and y–band imaging to select for optical dropout high-redshift candidates. We found the first PS1 high-redshift quasar (Morganson et al., arXiv:1109.6241: *The First High-redshift Quasar from Pan-STARRS*) at redshift 6 (see Figure IV.1.2); the prospect to discover $z = 7$ QSOs is promising.

B. Goldman, E. Bañados, N. Deacon,
T. Henning, N. Martin, E. Morganson,
H.-W. Rix, B. Venemans, F. Walter
In collaboration with partner institutes of the
PS1 Science Consortium,in particular the
Institute for Astronomy of the University of Hawaii;
as well as the ZAH of the University of Heidelberg
through the SFB 881 "The Milky Way"

IV.2 ARGOS: Laser guided Ground Layer Adaptive Optics for the LBT

ARGOS, the Advanced Rayleigh Ground layer adaptive Optics System for the LBT goals on the improvement of the image quality for both LUCI instruments by a factor of 2–3 in full width half maximum, which increases the spectroscopic efficiency by a factor of 4–9. All this will be provided for the full 4 arcmin field of view of both LUCI instruments and their multi-object capability by the means of 6 green Rayleigh laser guide stars. As ARGOS only corrects for the turbulence in the lower atmosphere (the so called ground layer) the full diffraction limit will not be reached. However, from the beginning ARGOS incooperated an on-axis diffraction limited upgrade with a Sodium laser into the design.

MPIA is one of the three bigger partners in the ARGOS consortium. In this role MPIA is responsible for the overall software and control, the calibration unit and the procurement of the dichroics, which separate the laser light to the wavefront sensor.

In the last year the swing arm, which holds the calibration unit, was assembled at MPIA and shipped to the LBT. The swing arm is built out of carbon fiber, a new material, which will be also very important for building new large scale telescopes to light weight their structure. In August the swing arm was then installed at the telescope.

The green laser light of the artificial guide stars has to be directed to the wavefront sensor. While the infrared light, used for science, should still reach the LUCI instruments. This is done by the means of a so called dichroic, which transmits light of certain wavelengths, in our case the near infrared, and reflects light of other wavelengths, in our case the green light of the laser guide star. Such dichroics are often used in optical instruments but the size and shape, which was needed for ARGOS was much bigger and more challenging as usual. During this year, the two dichroics needed for the right and left side of ARGOS have been delivered to MPIA. They have been tested for transmission and reflection. The result of the measurements shows that they comply with all specifications and even surpass some of them. With this positive result one of the most critical components of ARGOS are ready in time. At the end of next

Fig. IV.2.1: The swing arms in their shipping containment starting the long way from MPIA to the LBT at Mt. Graham, Arizona.

Credit: W. Gässler

Credit: W. Gässler

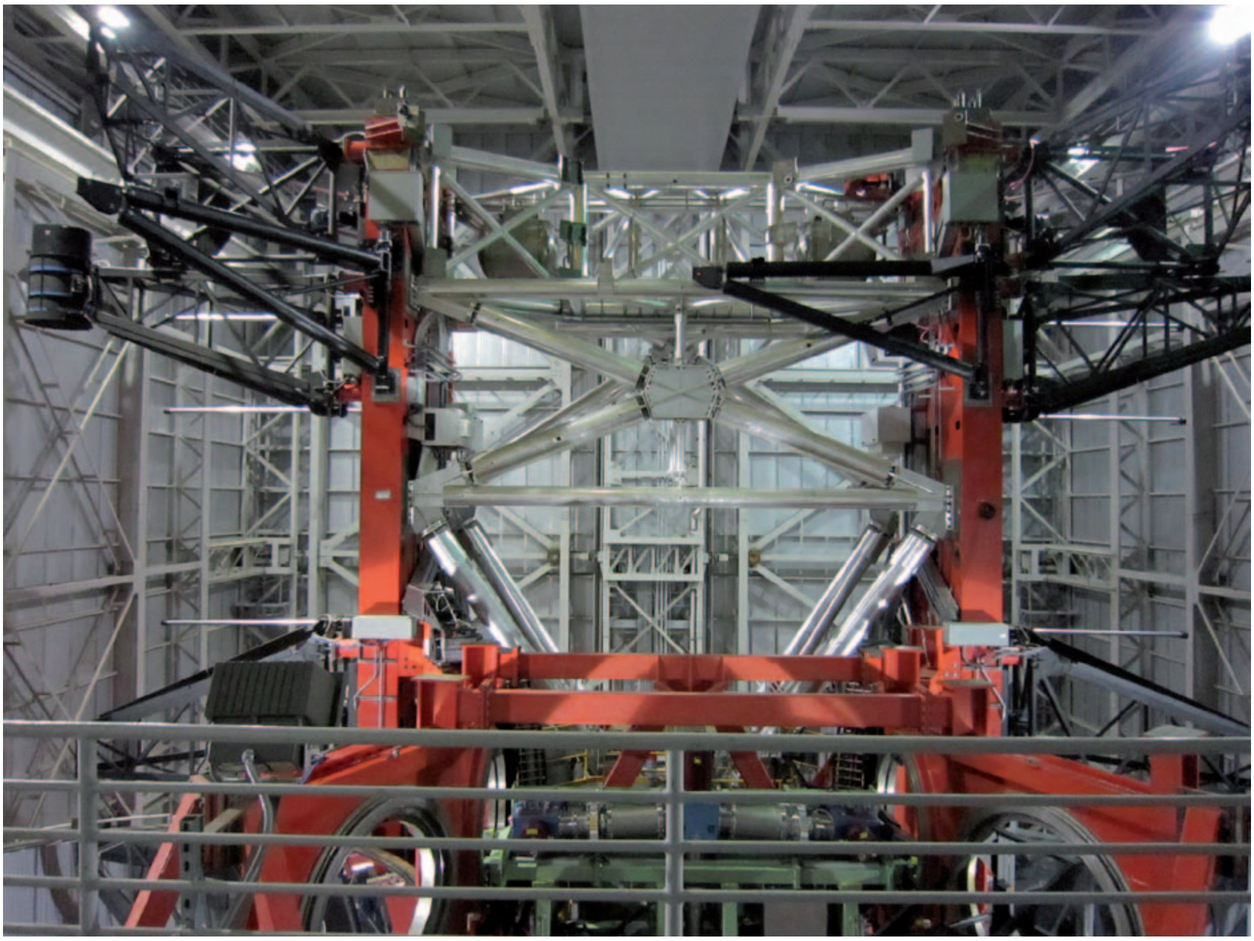
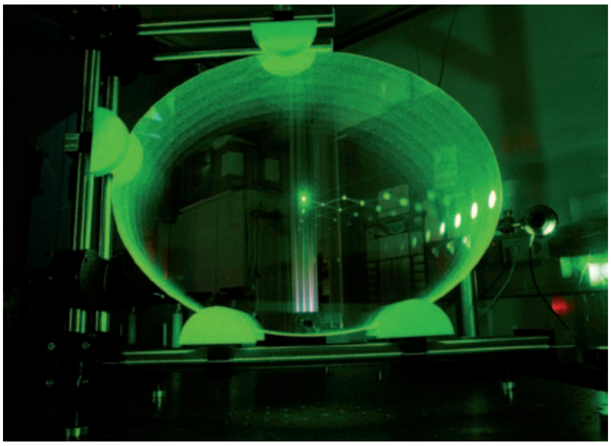


Fig. IV.2.2: The swing arms mounted on the LBT. They are retracted in their park position at the inner windbrace.

Fig. IV.2.3: The dichroic in its test mount. The reflection and transmission of the unit was measured and verified.

Credit: W. Gässler



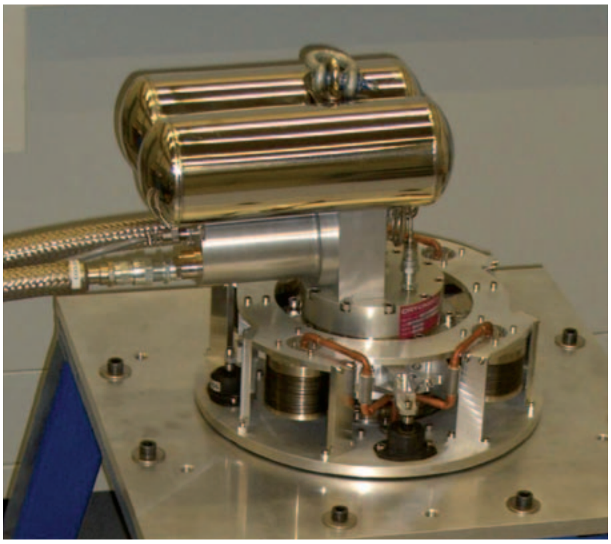
year the laser system will be installed at the telescope followed by the wavefront sensor in summer of the year after. Finally, in 2014, ARGOS is supposed to be handed over to the user community.

Involved at MPIA:
Wolfgang Gässler (Co-I), Thomas Blümchen,
Jose Borelli, Martin Kulas,
Michael Lehmitz, Diethard Peter.

Partners (local representatives only):
Wolfgang Gässler (MPIA),
Sebastian Rabien (MPE),
Simone Esposito (INAF-OAA),
Michael Loyd-Hardt (UA),
Andreas Quirrenbach (LSW),
Jesper Storm (AIP),
Richard Green (LBTO),
Udo Beckmann (MPIfR)

IV.3 MATISSE – Interferometric Imaging in the Mid-Infrared

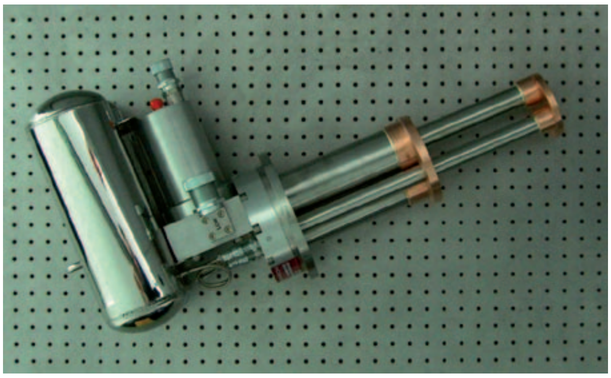
MATISSE – the Multi Aperture Mid-Infrared SpectroScopic Experiment – is one of two second generation instruments which had been selected by ESO for the VLTI at Paranal. Thus MATISSE is in a sense the successor of MIDI, the Mid-Infrared Interferometric Instrument, which has been built at MPIA and which is working on Paranal since 2003.



Credit: U. Graser

Fig. IV.3.1: Pulse tube cooler PTC 410 from Cryomech. The two copper plates mark the two stages.

Fig. IV.3.2: Head of Pulse tube cooler with damping system on test set-up.



Credit: U. Graser

MATISSE will combine the beams of up to four of the 8 m UTs (Unit Telescopes) or of up to four of the 1.8 m ATs (Auxiliary Telescopes) and thus will be able to measure in "closure phase mode", i.e. it offers an efficient capability for image reconstruction with a spatial resolution of up to 7 milliarcsec. The instrument will work at three wavelength bands: L (3.2 – 3.9 µm), M (4.5 – 5 µm), and N (8 – 13 µm), where the L and M band observations are performed simultaneously to the N band.

With the three different spectroscopic resolutions in the range of $R = 30 – 1500$ it will provide the basis for a fundamental analysis of the composition of gas and dust grains in various astrophysical environments. Key science programs for the ATs cover for example the formation and evolution of planetary systems, the birth of massive stars as well as the observation of the high-contrast environment of hot and evolved stars. With the UTs selected astrophysical programs such as the study of Active Galactic Nuclei and Extrasolar Planets shall be possible.

MATISSE is developed and built by a collaboration of the Observatoire de la Cote d'Azure, the MPIA, the MPI for Radio Astronomy in Bonn and two institutions (ASTRON/Dwingeloo and Leiden University) from the Netherlands. In this consortium MPIA is responsible for the cryogenics system, the entire control electronics, and the instrument control software.

After the successful Preliminary Design Review (PDR) in December 2010 the year 2011 was dominated by the preparations for the first part of the Final Design Review (FDR) in September 2011, where the cryogenic system and the design of the optics were reviewed by ESO. For the development of the cryostats several tests had to be performed. By using an auxiliary cryostat we specified the characteristics of the selected Pulse Tube Cooler PT410 from Cryomech (Fig. IV.3.1). With using such a device the induced vibrations are typically factors of 10–50 lower than with normal Closed Cycle Coolers of similar cooling power.

Besides the vibrations inside and outside of the test cryostat we also tested for the minimum temperatures to be reached with this kind of cooler at its first and second stage and for the temperature variations caused by the cooler when connected to a dummy cold optical bench (first stage) and a dummy detector (second stage). Here the copper braid used for this connection had to be opti-

Table. IV.3.1: The characteristic parameters of MATISSE.

Number of beams/ telescopes	4 (2 or 3 possible)	
Field of view	2 arcsec	
Spectral resolution	L/M	N
Low	$20 < R < 40$	$20 < R < 40$
Medium	$200 < R < 400$	$200 < R < 400$
High	$750 < R < 1250$	
Spatial resolution	0.007 arcsec	0.02 arcsec

Cryostat for:	L/M-Band (3 – 5 μm)	N-Band (8 – 13 μm)
Cooler	Pulse Tube Cooler (Cryomech PT 410)	
Detector	Hawai II RG 5 μm	Raytheon Aquarius
Pixel / pixel size	2 K × 2 K / 18 μm	1 K × 1 K / 30 μm
Cryostat: Size (h × w × l) / weight:	205 × 98 × 68 cm / 1500 kg	
Temperature Detector / Optics	40 K / 40 K	8 K / 40 K
Temperature stability	< 0.1 K	
Adjustable support (range / accuracy)	± 5 mm (in *h*, *x*, *y*) / 0.2 mm	
Cool-down time	< 3.5 days	
Accessibility of cold optics / detector	Accessible without dismounting the cryostat	
Detector displacement from vibrations	< 2 μm	< 3.5 μm

Table IV.3.2: The main requirements for the two cryostats.

mized between the contradicting properties of a sufficient cooling on the one hand and an efficient vibration damping on the other side.

In addition to these tests we had to perform several calculations, e.g. a Finite Element Analysis for the characterization of damage-prevention against Paranal-typical earth-quakes or the temperature distribution of the optics during cool-down. Also a thorough hazard analysis for the cryostat operation had to be delivered to ESO. Table IV.3.2 shows the main requirements for the two cryostats.

In parallel we continued in finalizing the design of the control electronics for the upcoming second part of the FDR in April 2012. Because of the limited space in the labs on Paranal a major effort had to flow into a compact design of the electronics. The control of 70 motors and of a lot of additional devices had to be packed into 3 cabinets.

Thomas Henning, Uwe Graser, Werner Laun, Michael Lehmitz, Marcus Mellein, Udo Neumann, Vianak Naranjo

IV.4 The EUCLID Dark Energy mission

EUCLID is a cosmology satellite mission in the framework of ESA's Cosmic Vision programme. It will characterize the nature of Dark Matter and Dark Energy by measuring the clustering of matter and the expansion history of the Universe since redshift 2. The task of designing and building the Euclid instruments is coordinated by a consortium of 13 European countries, bringing together scientists and engineers from more than 100 individual institutions. EUCLID will launch in 2020 to the Earth-Sun L2 point from where 15 000 square degrees of extragalactic sky will be observed over a six year mission duration.

Eighty years ago we seemed to know a lot about the Universe. Galaxies were identified as "island universes" similar to our own Milky Way, made up of stars and gas and dust. All constituents of mass seemed to have been found – until in the 1930s the outer rotation curves of galaxies proved to be incompatible with the mass of visible matter given the laws of gravitation. With the addition of similar discrepancies in galaxy clusters it became clear that a heretofore unrecognized and invisible component – coined "Dark Matter" – must contain 5 times more mass than the visible "Baryonic" matter that makes up stars and galaxies.

70 years later, by the end of the 1990s, another discrepancy was noticed. The expansion history of the Universe did not obey the law of gravitation yet again. Contrary to expectations, the expansion of the Universe was observed to be accelerating, requiring an additional ingredient, termed "Dark Energy", in the mass-energy content of the universe. This discovery was awarded with the Nobel-Prize in physics in 2011. Dark Energy must provide a mass density, to accommodate a near-euclidian flat space as identified by the COBE and WMAP missions, but at the same time deliver a repulsive effect.

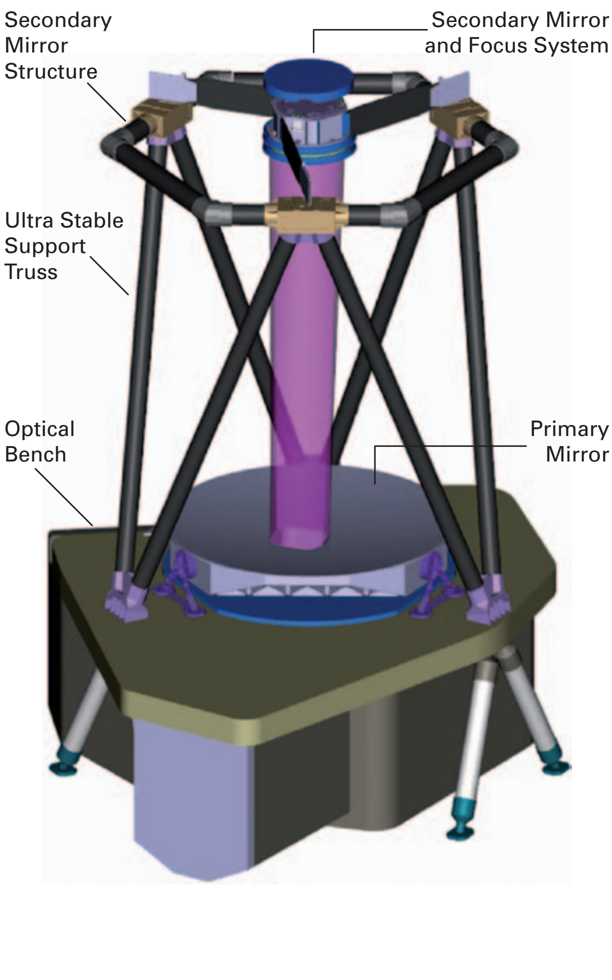
EUCLID: a quest for bringing light into darkness

ESA's EUCLID mission is designed to investigate the nature of Dark Energy, and Dark Matter, with the aim to pin down its equation of state parameters. These differ between various proposals for the nature of Dark Energy and can at the same time test predictions made by modified models of gravitation. EUCLID will utilize Weak Gravitational Lensing measurements to map the Dark Matter density in 3D-space and at the same time measure the expansion history of the Universe from $z = 2$ to today. This combination will allow scientists to determine the equation of state parameters by a factor of 30 better than any current or planned measurements for the next two decades.

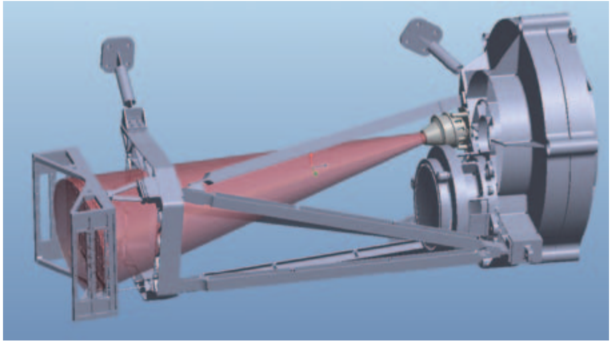
EUCLID's diagnostic require mapping of 15 000 square degrees of extragalactic sky with (1) high resolution imaging, (2) near-infrared spectroscopy, and (3) near-infrared photometry. While the former will be implemented in the VIS visual imager, MPIA's involvement lies mainly with the latter two, realized in the NISP (Near Infrared Spectro-Photometer) instrument. We are directly responsible for two hardware contributions, the NIR filters as well as a calibration light source to support the instrumental calibrations in flight. MPIA also fills the position of instrument scientist and image simulator for the photometry channel and is hence centrally involved in the planning and definition aspects of the mission.

The mission was officially selected for the 2nd M-class launch slot in ESA's Cosmic Vision Programme in late

Fig. IV.4.1: An early concept of the Euclid telescope. A 1.2 m-diameter off-axis mirror will feed the two instruments VIS and NISP, mounted to the lower side of the optical bench. The light-path will be deliberately simple to allow a very high image quality for the VIS imager (from the EUCLID Red Book, ESA, 2011).



Credit: A. Anselmi, Thales Alenia Space Italia



Credit: MPIA

Fig. IV.4.2: Current mechano-optical design of the Near Infrared Spectrophotometer (NISP) onboard EUCLID. MPIA's contribution lies in the supervision of the scientific performance of NISP, the internal Calibration Source, needed to calibrate the instrument's detectors, as well as the three infrared science filters for NISP.

2011 and is awaiting its final adoption in mid 2012, with the implementation phase scheduled to start immediately thereafter. Overall, Germany is mostly involved with NISP – the optical assembly is provided by the MPE – and the German EUCLID national data center with contributions by the Universities in Bonn, LMU Munich, MPE and MPIA. Part of the institute's involvement is being funded through the DLR. This includes four positions for instrument scientist, image simulations, calibrations, and hardware, as well as in-house contributions concentrated on the science side.

MPIA hardware contributions: Near infrared filters and calibration source

While we are not responsible for mechanisms, the NIR filters provide specific challenges with a diameter of 140mm, necessitated by the $0.7° \times 0.7°$-wide field of view of EUCLID. These diameters are larger by a factor of three compared to any of the WFC3/IR filters on HST and by a factor of two compared to JWST's NIRcam. Aside from the mere material challenge of a pound of glass being homogeneously coated to very high accuracy, the three filter bandpasses (Y, J, H) have rather stringent requirements on throughput, out-of-band-blocking, and shape.

The NISP calibration source is being designed to provide the photometric accuracy levels required by the mission. An overall 1.5 % accuracy for all positions and epochs of the survey is the basis for the photometric redshifts to be computed for all of the faint galaxies to be used in the weak lensing diagnostic. This leaves little margin for the characterization of the detector array (16 Hawaii 2RG chips). The calibration source therefore has to provide flat-field and non-linearity characteristics of the arrays in flight and monitor their radiation-induced degradation with increasing mission duration.

The demands of the filter and calibration source design combined with the overall development of the mission will make for very interesting years ahead of us.

Legacy science: A place to participate

Scientifically, EUCLID offers endless opportunities beyond the core cosmology science. 15 000 square degrees of imaging data of a 5000–9000 Å band at 0.1″ sampling, complemented with somewhat undersampled NIR photometry at 0.3″ pixel scale, as well as slit-less spectroscopy will provide data input to topics ranging from AGN and galaxy evolution to Milky Way science, and from supernovae to planet searches. EUCLID's extensive Science Working Groups are starting to plan projects and opportunities in these legacy science areas, to exploit imaging data of billions of objects and spectroscopy of several tens of millions.

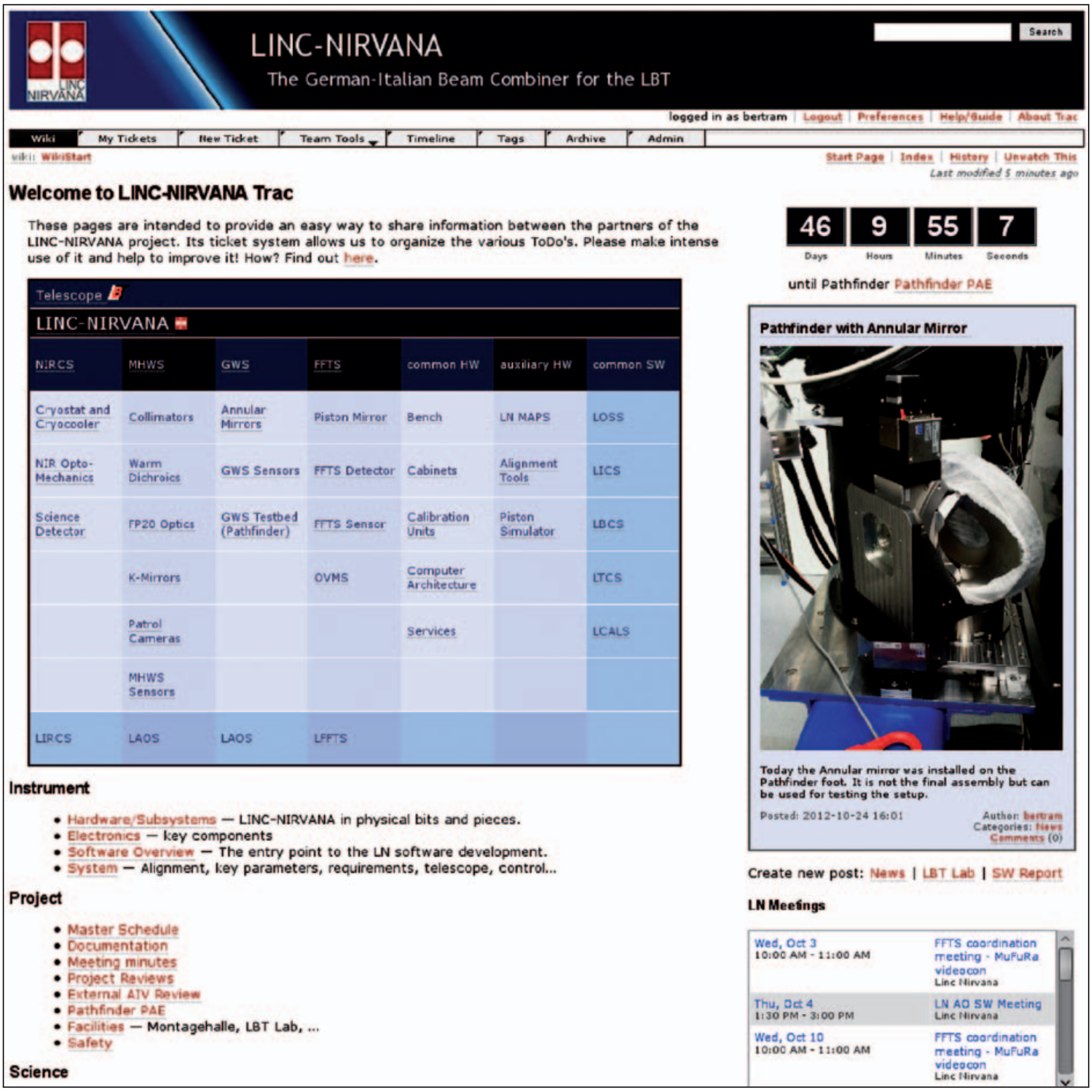
Knud Jahnke, Rory Holmes, Gregor Seidel, Felix Hormuth, Stefanie Wachter

IV.5 Special Developments in the Technical Departments

TRAC: A versatile Teamwork Platform used in Instrumentation Development

The accessibility, organization and presentation of all project related information is a key to efficient collaboration within development teams. The value of a structured information platform increases with the number of team members and the duration of the projects. It provides a common pool of knowledge to the various disciplines within the development team. And it helps the Systems Engineering to manage the interdependencies and to monitor the progress in the different areas and phases of the development. A wide range of commercial groupware solutions promise help by supplying collaboration tools, such as centralized file exchange, document management, task management, discussion forums and wikis.

Fig. IV.5.1: : The wiki start page for LINC-NIRVANA's Trac



Credit: MPIA

Credit: MPIA

Fig. IV.5.2: Each subsystem of LINC-NIRVANA has a wiki page with all related information, including meeting minutes, documents, notes and tickets.

TRAC at a glance

TRAC (http://trac.edgewall.org) is a free and open source groupware alternative. Mainly developed as web-based management tool for software projects, it supports software development teams with tools that are specific to their needs, such as software configuration management / version control or a code browser. Although made to help software developers, its minimalist approach allows adapting TRAC to a wide range of projects, including instrumentation development.

At MPIA several software and instrumentation projects now make use of TRAC and of many of its features:

- ***The wiki.*** It is the main access point for the team members. A simple interface allows them to create and edit wiki pages. The team can gather content; the pages can be structured and formatted in a comfortably readable way. Pictures and other types of media can be embedded, as well as content from other TRAC modules like the ticket system or the blog plugin. Files can be attached and referenced within the wiki page.
- ***The ticket system.*** It allows following up issues that are identified in the course of the project. For software projects tickets are often used to describe bugs and their solutions. But tickets can also be used to organize the workflow and dependencies when developing hardware. Tickets can be associated with project milestones and with entities such as systems or

components. The owner of the ticket is in charge of the underlying task. Additional information, such as due dates or dependencies on other tickets can be reflected. All information is kept in a database. A simple interface allows to query and filter the tickets and, by that, to monitor the progress of the project or to identify open issues for upcoming milestones.

- ***The version control system.*** Each TRAC project is associated with a subversion repository. For software development projects it is the place to store the code, but it can also be used to archive and control versions of documents.
- ***Seamless interaction.*** Within TRAC it is very simple to introduce references to tickets, wiki pages, files in the repository, blog entries etc. All content within TRAC is also searchable.
- ***Expandability.*** TRAC capabilities can easily be expanded by adding plugins. There is an active community developing a wide variety of plugins, such as the blogging system, user account management or Latex support in wiki pages. TRAC and its plugins are developed in the Python programming language; with reasonable effort it is possible to develop custom solutions needed for a project.

TRAC and LINC-NIRVANA

LINC-NIRVANA introduced TRAC in 2010 and uses it since with great success. More than 70 team members and reviewers from inside and outside of MPIA have access to LINC-NIRVANA's TRAC.

The project uses tickets to organize and follow up most development activities. Each team member involved in an activity gets informed by email about updates. The tickets increase the efficiency of status meetings – they help to stay focused and provide all important information on its subject in a commonly accessible place. The tickets have demonstrated to be very helpful when collaborating with partners in different institutes.

All project related documentation is archived in TRAC and is easily accessible in various places on the wiki, depending on their context. So are meeting minutes and notes, which are stored as blog posts.

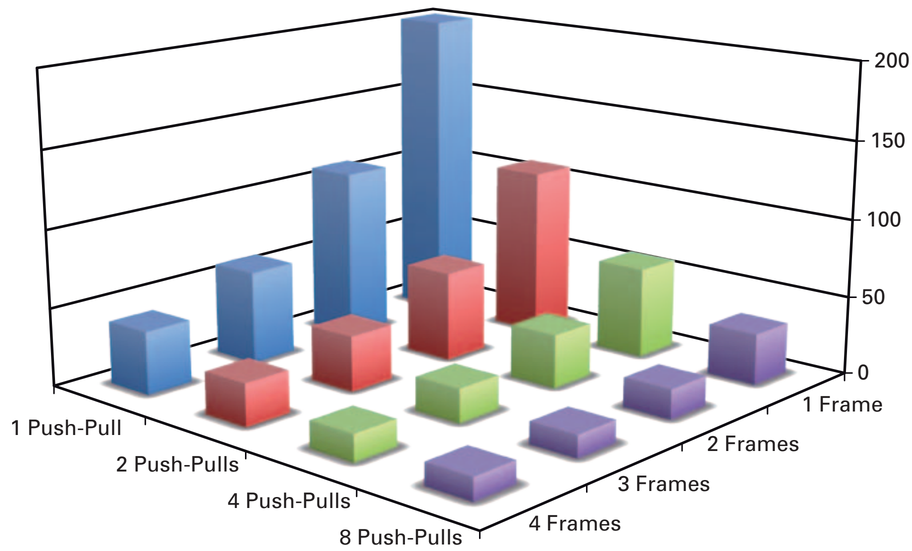
Thomas Bertram, Florian Briegel

Interaction Matrix Calibration for Adaptive Optics: What is the best method?

For an adaptive optics (AO) system it is necessary to characterize how the deformable mirror (DM) interacts with the complete optical system up to the wavefront sensor. This procedure, commonly referred to as "calibrating the interaction matrix" (a matrix which is then inverted to produce the matrix for reconstructing the wavefront) is a process which is a key to achieve an optimal control of the DM. Members of the technical department at MPIA, working together with graduate student Xianyu Zhang and colleagues from INAF, have determined an optimal method for performing this calibration. These results appear in the article "Calibrating the interaction matrix for the LINC-NIRVANA high layer wavefont sensor" which was recently published in the journal Optics Express.

Traditionally, interaction matrices have been calibrated by commanding the DM to a sequence of well-defined shapes, and, at each step in the sequence, taking a measurement of the light pattern seen by the sensor. But this process is affected by various sources of noise.

Fig. IV.5.3: See text for details



Credit: MPIA

More recently, engineers and astronomers have determined that measurement noise can be reduced using standard statistical techniques. By alternating between each shape and its negative, and taking multiple measurements of each state, these data can be combined to get a more accurate value. This technique is called the "push-pull" method.

For example, one of the fundamental shapes that is applied in the sequence is "pure focus." This is a parabolic shape that appears somewhat like the shape of a cereal bowl. With the push-pull method, both the right-side-up cereal bowl and the upside-down cereal bowl shape are measured, and these shapes are measured several times each. All data is then combined to produce a single measurement.

But if there is time to take only 8 measurements per mode, which is better: To take 4 positives in sequence and then 4 negatives; or to alternate, positive-then-negative, 4 times? Or is a compromise best: 2 positives and 2 negatives repeated twice?

Prior to this study, engineers and astronomers based this decision on intuition. But from the study performed at MPIA, it has been determined that it is the second option listed above, alternating positive and then negative, one frame at a time, which gives the best result. This is shown in Figure IV.5.3 taken from the publication. The purple column on the far right of the figure is shorter than the blue column on the far left (and also shorter than the orange and green columns in between). Since a smaller value indicates a more well-determined interaction matrix in this figure, it is clear that 8 push-pulls, with one frame per dwell, is the preferred method.

Albert Conrad, Thomas Bertram,
Florian Briegel, Frank Kittmann,
Daniel Meschke, Fulvio De Bonis,
Jürgen Berwein

V People and Events

V.1 Looking back at 2011

Exactly three years after the foundation we could celebrate the inauguration of the Haus der Astronomie (literally: House of Astronomy (HdA)) on December 16, 2011 with a number of prominent guests on the campus of the MPIA. Within the special chapter V.2 of this annual report we present details about this very important event and show with many illustrations particularly some highlights from the emergence of the building. Of course, we also report about organizational developments and the mission of the HdA. But the year 2011 had to offer many other remarkable events as the following section will show.

Academic life and conferences

One of the first special events throughout the year was a meeting titled *Astronomy meets Business* which took place on January 27 in the MPIA lecture hall and which was also attended by colleagues from the other astronomical institutes in Heidelberg.

Following a suggestion by the students and postdocs, MPIA had invited a number of representatives from industry, the Federal Ministry of Education and Research (BMBF), and the German Center for Aerospace (DLR). The aim of this event was to discuss the chances for astrophysicists to pursue a professional career outside scientific institutions. Also aimed on the opportunities for scientists was the *Naturejobs Conference* on May 9 at the European Molecular Biology Laboratory (EMBL) in Heidelberg. MPIA supported this conference with a booth and a presentation.

Part of the academic life at MPIA was again an *Internal Symposium* on May 25. The all-day event with scientific presentations by students and postdocs from the different departments provided a wonderful opportunity to get an overview about the manifold research projects at the Institute. In 2011, also the new *Visitor Colloquium* was launched – a platform for high quality talks given by special scientific visitors of the Institute.

Furthermore, we introduced *welcome events* for new students and postdocs at the Institute and (for about three

Fig. V.1.1: Members of the Board of Trustees and the institute management during a tour through the new HdA building in November 2011. From left to rigth: Oliver Krause (MPIA), Stephan Plenz (Heidelberger Druck), Markus Pössel (HdA/MPIA), Thomas Henning (MPIA), Renate Fischer (MWK), Klaus Tschira (KTS), Lisa Kaltenegger (MPIA), Matthias Voss (MPIA), Klaus Jäger (MPIA), Susanne Mellinghoff (MPG), Reinhold Ewald (ESA), Roland Gredel (MPIA)

Credit: D.Anders

times a year) a new, so-called, *Faculty Meeting*. In this meeting MPIA senior scientists and research group leaders are invited to discuss scientific and organizational matters with the institute management. Due to its special composition, the Faculty Meeting complements the existing committees such as the Institute- or the Scientific Advisory Board Meeting.

Like every year, MPIA scientists organized local and external conferences or participated significantly in the organization and management of other meetings. This included two workshops at Ringberg Castle (*Baroclinic Instability and Proto – Planetary Accretion Discs*, June 14–18, as well as *Transport Processes and Accretion in Young Stellar Objects*, February 7–11) and, as in recent years, the *IMPRS Summer School* at the Max Planck House Heidelberg (August 1–5) which was combined with a trip to MPIA. This time, the workshop was about *Characterizing Exoplanets – from Formation to Atmospheres*.

MPIA was also heavily involved in the fall meeting of the German Astronomical Society (AG) through organizational and financial support, but also through scientific presentations and Splinter Meetings, teacher training, and a special meeting for Public Outreach in Astronomy. The conference entitled *Surveys and Simulations – The Real and the Virtual Universe* was held at Heidelberg University between September 19 and 23. In the numerous PR activities surrounding the conference also for the first time the HdA was involved since the new and nearly finished building was presented to numerous visitors of the conference in several organized guided tours.

Public outreach and special guests at MPIA

Again this year employees of MPIA/HdA where very active in order to present astrophysics to a broader public (see also Chapter V.2).

A "fast-sell" since 2006 is the Astronomy Lecture Series on Sunday Morning and once again more than 1000 people attended the 8 popular presentations on Königstuhl in early summer 2011.

A total of 15 MPIA scientists also participated in the 70 presentations of the lecture series *(Uni)versum für Alle* in the Peterkirche Heidelberg. The lectures which took place almost daily at noon between April and July were organized by the Center for Astronomy of Heidelberg University (ZAH).

It has long been an important issue for MPIA to inspire young people for physics and astronomy and this was also one reason for the institute management to stand up for the HdA. Thus, also in 2011, the Institute and the HdA team organized a local program during the Girls' Day (April 14), provided (together with ZAH institutes) a one-week *internship for pupils from high school* (October 24–28), supported in July and August the *International Science School of Heidelberg* with internships, contributed to *Explore Science* in Mannheim (May 19–21) organized by the Klaus Tschira Foundation (KTS), and supported a ceremony at MPIA held by the Lord Mayor of Heidelberg, Eckart Würzner, to award 17 schools from Heidelberg and their successful energy teams (April 19).

Even before the official opening the HdA building has been shown to visitors at various events during the last quarter of the year. Besides the above mentioned tours during the AG meeting, this was the case at the Max-Planck-Day (November 11), at an information day for partners and friends of the HdA (November 25), during the visit of the MPIA Board of Trustees (November 29,

Fig. V.1.2: Great interest to get hold of the new book about MPIAs history after the presentation of *"Im Himmel über Heidelberg"* in the lecture hall.

Credit: D.Anders

Credit: D.Anders

Fig. V.1.3: The author, Dietrich Lemke (*left*), in conversation with Immo Appenzeller, the former director of MPIA's neighbour institute on Königstuhl, the Landessternwarte.

see Fig.V.1.1), and when the German-Japan Round Table (organized by KTS) came up to the Königstuhl (December 1).

And on November 15, we had the first event in the HdA's Klaus Tschira Auditorium. We celebrated with a special scientific symposium including international guests the retirement of Jakob Staude, the long-time head of public outreach at MPIA and chief editor of *Sterne und Weltraum*. Even the editorial office of this astronomy magazine (published by Spektrum) which has been produced for decades at MPIA moved into the new building together with the MPIA graphics department and, of course, the HdA-team already on September 26.

If someone wants to learn more about the institute – from its beginnings in the 1960s until the construction of the HdA – one now has a new opportunity: since 2011 we have released an intriguing book authored by MPIA scientist Dietrich Lemke entitled *Im Himmel über Heidelberg*. The book was presented at a ceremony held in the MPIA lecture hall on May 23 (see Fig.V.1.2 and 3).

Other developments at the Institute

What has been described in the previous chapters I to IV represents only a relatively small part of the total scientific or technical activities done at MPIA in 2011. Since we vary the topics described in the annual reports over the years to avoid excessive lengths we recommend to look at several annual reports for a more complete picture. This explains that some of the currently very important topics for MPIA are only marginally mentioned in Chapter I to IV or even be missing. Therefore, we would like to mention here for example, that the technical departments in collaboration with colleagues at Calar Alto successfully managed to solve a very difficult problem at the mount of the 3.5 m telescope at the beginning of the year and therefore secured the continued operation of the telescope. This was of particular importance since the new agreement between the Max Planck Society and its Spanish counterpart, the CSIC, entered into force. This agreement regulates the continued operation of CAHA until 2018.

The year 2011 was also another successful year in the use of HERSCHEL – both from a scientific as well as from a technical perspective, because the currently largest space telescope with instrumental contributions from MPIA worked flawlessly and provided excellent data for MPIA scientists which are involved in several key projects.

It is also remarkable that we already successfully completed the work on the instruments MIRI and NIRSPEC for the James Webb Space Telescope (JWST) which is expected for launch in 2018. And finally, we should also mention that we have started further initiatives to improve the long-term project planning and project management (for example through a special course about *Scientific Project Management* kindly held by Michael Perryman in February 2011).

Bereavement

Besides all these positive events, there was unfortunately cause for mourning. On May 7, suddenly and unexpectedly died Crystal Brasseur. Before she became a PhD student in the Galaxy and Cosmology department of MPIA, she completed her M.Sc. degree in Astronomy in 2009 at the University of Victoria. We will keep her in our thoughts.

Klaus Jäger, Thomas Henning, Markus Pössel, Axel M. Quetz, Hans-Walter Rix, Mathias Voss

V.2 Haus der Astronomie – Centre for Astronomy Education and Outreach

2011 was a crucial year for the Haus der Astronomie (HdA). Where we had spent the last two years establishing the HdA as an institution, this December saw the official opening of our spectacular, galaxy-shaped building. Thus, our mission this year was to hit the ground running: As soon as possible after the opening, we wanted to make the best use possible of the building and the new opportunity it represented. That meant having almost all of the center's planned outreach activities already in place by the end of the year.

We started into 2011 with an experienced team: Markus Pössel as the HdA's Managing Scientist (funded by Max Planck Society) had been with the center since 2009. Olaf Fischer (funded by the City of Heidelberg's Foundation for Youth and Science), our resident specialist for high-school astronomy, had moved to the HdA in late 2009. Carolin Liefke (funded by the Klaus Tschira Foundation and Baden-Württemberg's Ministry of Science and Research), whose focus areas include student research and university teaching for future physics teachers, has been with us since spring 2010. Cecilia Scorza, who specializes in middle school astronomy education, joined us in 2009; since early 2011, she works at HdA as a project scientist funded by the Special Research Programme SFB 881 "The Milky Way System". Jakob Staude, one of the driving forces behind the HdA project as a whole, remains our mentor-in-residence. In May, we were joined by Natalie Fischer, who became the National Project Manager for the EU-UNAWE project, which aims to bring astronomy to young, disadvantaged children; also for EU-UNAWE, the developmental psychologist, Anita Mancino, joined our team in September. Also in September, two teachers (Gymnasium and Realschule), on loan from Baden-Württemberg's Ministry of Education, joined our team: Alexander Ludwig and Tobias Schultz will spend 50 % of their time in the HdA, where, among other tasks, they will be involved in holding high-school student workshops. Intern Marcel Frommelt and student assistants Stephan Fraß and Sophia Haude completed our roster.

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

Fig. V.2.1: The Haus der Astronomy at dusk (30 November 2011).

Credit: D. Gouliermis

Whereas scientific exchange in its usual incarnation, as meetings and conferences, is contingent on the use of our new building and will come into its own starting in 2012, our outreach and educational activities in 2011 were many and manifold.

In the area of outreach, we continue to combine „classic“ astronomical PR, online outreach and public events. In particular, we continued our work as German node of the Eso Science Outreach Network, where our contributions include German translations of all Eso press releases (Liefke / Pössel) and, this year, support of the Open Day at Eso headquarters in Garching (Liefke). As far as public events go, our highlight was once more the Klaus Tschira Foundation's five-day family science festival "Explore Science" in May (with a total of 55 000 visitors), where we presented hands-on stations about basic astronomy and spectroscopy.

Additional events included information booths, complete with sidewalk astronomy activities, at both the "Lange Nacht der Museen" (literally the "Long Night of the Museums") at the Planetarium Mannheim and at Heidelberg University's "Uni-Meile", the street fair celebrating the university's 625th anniversary. HdA staff also gave more than a dozen public talks, including six that were part of the lunchtime lecture series on basic astronomy organized by J. Wambsganss of Heidelberg University's Center for Astronomy.

Our visualization efforts also took off this year as, with the help of scientists from MPIA, from Heidelberg University and the Heidelberg Institute for Theoretical Studies (Volker Springel, Andreas Bauer, Hubert Klahr, Mario Flock, Kees Dullemond, Ralf Klessen), we produced a set of brief movies for use in our fulldome projection system. Even the background music was composed and produced by ourselves in the free time KLaus Jäger). The movies were premiered at the HdA's official opening, and have been used in our work ever since.

On the education side, "Wissenschaft in die Schulen!" (literally "Science into the schools!", abbreviated WIS) in cooperation with the popular astronomy magazine Sterne und Weltraum remains our flagship project. HdA senior staff member Olaf Fischer, in charge of WIS-Astronomy, and his team of (mostly external) authors created 24 sets of curricular materials – two per months – for teachers to use in bringing cutting-edge astronomy into their classrooms. Each set is directly linked to an article or news item in a current issue of Sterne und Weltraum. The HdA's activities for WIS-Astronomy are kindly supported by the Reiff Foundation for Amateur Astronomy.

The development of hands-on experiments remains another mainstay of our work. This year saw the production of 15 infrared kits (C. Scorza and M. Frommelt) funded by he Baden-Württemberg Stiftung and the development and production (N. Fischer and C. Scorza

Fig. V.2.2a: Two neigbouring buildings: the main MPIA building and, still under construction, the HdA building. (2 March 2011)

Credit: M. Pössel/HdA

Credit: M. Pössel/HdA

Fig. V.2.2b: Installing façade elements. (20 April 2011)

Fig. V.2.2c: Inside, the building's basic structure is now clearly defined. (22 March 2011)

Credit: M. Pössel/HdA

Credit: M. Pössel/HdA

Fig. V.2.2d: Scaffolding in the Klaus Tschira auditorium in preparation for the installation of the planetarium dome (20 April 2011)


Credit: M. Pössel/HdA

Fig. V.2.3a: Inside, the offices are taking shape. (9 September 2011)

in cooperation with Astronomieschule e.V.) of the EU-UNAWE astronomy kit "An adventure in astronomy – a trip through the universe for elementary students", again funded by the Baden-Württemberg Stiftung. C. Scorza and A. Ludwig also developed hands-on material for the interplanetary probe Mars Express for ESA's European Space Operations Center in Darmstadt.

Our activities in training teachers – and aspiring teachers – span the whole spectrum from initial teacher education to in-service training. Teacher education at the University of Heidelberg featured two seminars ("Astronomy in the headlines" and "The Milky Way", C. Liefke and O. Fischer), while N. Fischer held a lecture on "Basic Astronomy in School" at Heidelberg's University of Education (Pädagogische Hochschule). Olaf Fischer and Cecilia Scorza (co-)advised on a total of three "Staatsexamensarbeiten", the research-oriented thesis aspiring teachers need to write as a requirement for their degree.

In-service teacher training took place • locally, e.g. teacher training on the occasion of the Annual Meeting of the Astronomische Gesellschaft in Heidelberg (O. Fischer, C. Liefke), four teacher training sessions for the UNAWE elementary school kit (N. Fischer), training for kindergarten teachers in cooperation with Forscherstation Heidelberg (N. Fischer), • regionally, including

Fig. V.2.3b: Ready for work: the new HdA offices. (18 October 2011)


Credit: M. Pössel/HdA

Credit: M. Pössel/HdA

Fig. V.2.4a: Model telescopes and astronomical images: The exhibition in the HdA foyer. (21 December 2011)

Credit: M. Pössel/HdA

Fig. V.2.4b: Astronomical images along the ramp. (18 October 2011)

Credit: M. Pössel/HdA

Fig. V.2.4c: The UNAWE room is ready to receive our youngest visitors. (28 October 2011)

Credit: M. Pössel/HdA

Fig. V.2.5: HdA staff member Natalie Fischer at the joint presentation of Haus der Astronomie and Astronomieschule e.V. at Explore Science, the Klaus Tschira Foundation's festival of science in Mannheim (20 May 2011)

the interdisciplinary teacher training "Let's go to Mars" for teachers from Baden-Württemberg (O. Fischer, C. Scorza, M. Pössel, T. Schultz, A. Ludwig); participation in teacher training activities in Biberach, Stuttgart, Marbach (all C. Scorza and O. Fischer), Heilbronn (C. Scorza), and • nationally: National Astronomy Teacher Training in Jena (C. Liefke), E-HOU Teacher Training at the Stockert Radio Telescope, teacher training in Sonneberg / Thuringia (both O. Fischer and C. Scorza).

We also reached out directly to pupils and preschool children: In a total of 15 workshops at the HdA for various age groups with a total of 530 participants, making use of the brand-new building (C. Scorza, T. Schultz, N. Fischer, A. Mancino), an astronomy course for the Hector-Kinderakademie (N. Fischer), courses at the Deutsche Schülerakademie Rostock (O. Fischer) and at the Science Academy Baden-Württemberg in Adelsheim (O. Fischer, C. Scorza) and an event for pupils on the 11th of November, namely Max Planck Day (O. Fischer, C. Liefke, M. Pössel, C. Scorza). Outreach to younger children is in the context of our international collaboration as German node of the EU-funded part of the global "Universe Awareness" project (EU-UNAWE; C. Scorza, N. Fischer, A. Mancino). The goal of UNAWE is to use the beauty and grandeur of the Universe to inspire young children, encourage them to develop an interest in science and technology, and introduce them to ideas of global citizenship and tolerance. We are very pleased that Theresia Bauer, Baden-Württemberg's minister for science, research and the arts, has agreed to act as patron to EU-UNAWE in Baden-Württemberg, while the Astronomische Gesellschaft has agreed to act as the program's patron throughout Germany.

A key component of science literacy is first-hand research experience for high-school students. To this end, we continued our collaboration with the International

Fig. V.2.6: Autumnal impressions of an earthbound galaxy (30 November 2011)

Credit: D. Gouliermis

Astronomical Search Collaboration (IASC) on the IASC-Pan-Starrs asteroid search (high-school students searching for asteroids in Pan-Starrs image data, with a realistic chance of discovering previously unknown main-belt asteroids), with Carolin Liefke supporting a total of 12 German high-school groups participating in two search campaign. Most of our high-school student research activities involve much smaller groups, including students from the Hector-Seminar (C. Liefke, M. Pössel with A. van der Wel and J. Bouwman), the International Summer Science School Heidelberg (M. Pössel) and career orientation as well as regular interns (O. Fischer, C. Scorza, M. Frommelt, T. Schultz, A. Ludwig, C. Liefke, M. Pössel).

Our intern Marcel Frommelt made his own contribution to our program (sponsored by C. Scorza) with a research project on a balloon mission to Titan – which included an experimental part (a home-made balloon with camera launched into the stratosphere) and placed first in the regional and third in the Baden-Württemberg State competition "Jugend forscht" in the category of Geo- and Space Sciences.

Networking, cooperation and, given that we are a relatively new institution, outreach to the other members of the outreach community remain an important part of our work. Notably, we guided more than 350 participants on tours of the HdA construction site, including numerous participants of the Astronomische Gesellschaft's annual meeting which, this year, took place in Heidelberg. To keep our partner institutions up to date, we also organized a special "HdA day" in our just-finished building in November. An anniversary colloquium on the occasion of the nominal retirement of MPIA/ HdA member Jakob Staude, who serves as one of the publishers of Sterne und Weltraum, also in November, provided excellent opportunities for introducing ourselves to additional members of the German outreach community. Last but certainly not least, our grand opening, attended by, among others, Baden-Württemberg State Minister for Science, Research and the Arts Theresia Bauer, Baden-Württemberg State Minister for Education, Youth and Sports Gabriele Warminski-Leitheußer, Peter Gruss as President of the Max Planck Society, Eckart Würzner as Lord Mayor of the City of Heidelberg, Bernhard Eitel as Rector of the

Credit: C. Liefke/HdA

Fig. V.2.7: The main protagonists at the official opening, left to right: the building's architect, Manfred Bernhardt; MPIA director Thomas Henning; Bernhard Eitel, rector of Heidelberg University; MPIA director Hans-Walter Rix; Markus Pössel, managing scientist of the HdA; Peter Gruß, president of the Max Planck Society; Theresia Bauer, minister for science, research and the arts of the State of Baden-Württemberg; Klaus Tschira; Gabriele Warminski-Leitheußer, minister for education, youth and sports of the State of Baden-Württemberg; Eckart Würzner, Lord-mayor of Heidelberg; Mathias Voss, head of administration, MPIA; Klaus Jäger, scientific coordinator, MPIA, and Jakob Staude. (16 December 2011).

University of Heidelberg and our principal benefactor, Klaus Tschira, took place on December 16. The opening lecture held by Michael Kramer of the Max Planck Institute for Radio Astronomy. The building was presented both formally (in a small-scale meeting beforehand) and symbolically (as part of the opening ceremony) by Klaus Tschira to the Max Planck Society.

Internationally, our main collaborations are in the framework of the EU-UNAWE network (that is, with our counterparts in Italy, the Netherlands, the United Kingdom, South Africa and Spain) as well as with Chile (in cooperation with the Heidelberg University's Center for Astronomy and its Centre of Excellence in Chile).

Key strands of our network are tied to specific persons: Olaf Fischer and Cecilia Scorza are members of the Schulkommission (School's committee) of the Astronomische Gesellschaft, and Fischer was elected its chairman this September. Cecilia Scorza is the German coordinator for the European Association for Astronomy Education and for the EU-UNAWE program, as well as a member of IAU commission 46, "Astronomy Education and Development".

We are also pleased to announce that, at this year's meeting of Astronomische Gesellschaft, Olaf Fischer was awarded the Hans-Ludwig Neumann Award for Astronomy Education in Schools while, at the same meeting, our benefactor Klaus Tschira was made an honorary member of the Astronomische Gesellschaft – a rare honour bestowed upon those who have furthered the cause of astronomy in an exemplary manner; the Astronomische Gesellschaft explicitly mentions the Haus der Astronomie as a key example of Klaus Tschira's contributions to astronomy.

The highlight of 2011 was, without doubt, the opening of the Haus der Astronomie's new, galaxy-shaped building. The building had begun the year as not much more than a concrete shell (with windows, to be sure). It gained shape, a planetarium dome, lecture-hall chairs, planetarium projectors, a clean white interior and a spectacular exterior facade, interior partition walls and office furniture. After moving in the last week of September, HdA staff began to discover the building, its rooms and their functionality. Of particular interest, of course, was the digital Zeiss planetarium, which includes a show manager for use e.g. with our own visualizations, and the Uniview software for visualizing astronomical catalogue data.

If the last months of 2011 showed one thing, it is that 2012 as the year for fully implementing HdA activities in their new setting, should be very exciting! The year 2011 we will remember as the year the Haus der Astronomie found its home – and hit the ground running.

Markus Pössel, Natalie Fischer,
Olaf Fischer, Carolin Liefke,
Alexander Ludwig, Anita Mancino,
Tobias Schultz, Cecilia Scorza,
Jakob Staude, Thomas Henning,
Hans-Walter Rix, Klaus Jäger,
Mathias Voss, Frank Witzel

V.3 Honors and Awards

Ernst Patzer Prize

The annually presented *Ernst Patzer 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.

The Award 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.

This year's prize winners were:

Elisabetta Caffau, Postdoc at the Center for Astronomy of Heidelberg University (ZAH), for her paper "An extremely primitive star in the Galactic halo" (2011, Nature 477, 67–69).

Alexander Karim, IMPRS PhD student at MPIA, for his publication "The star formation history of mass-selected galaxies in the COSMOS field" (2011, Astrophysical Journal 730(2), 1–31).

Fig. V.3.1: *Elisabetta Caffau*

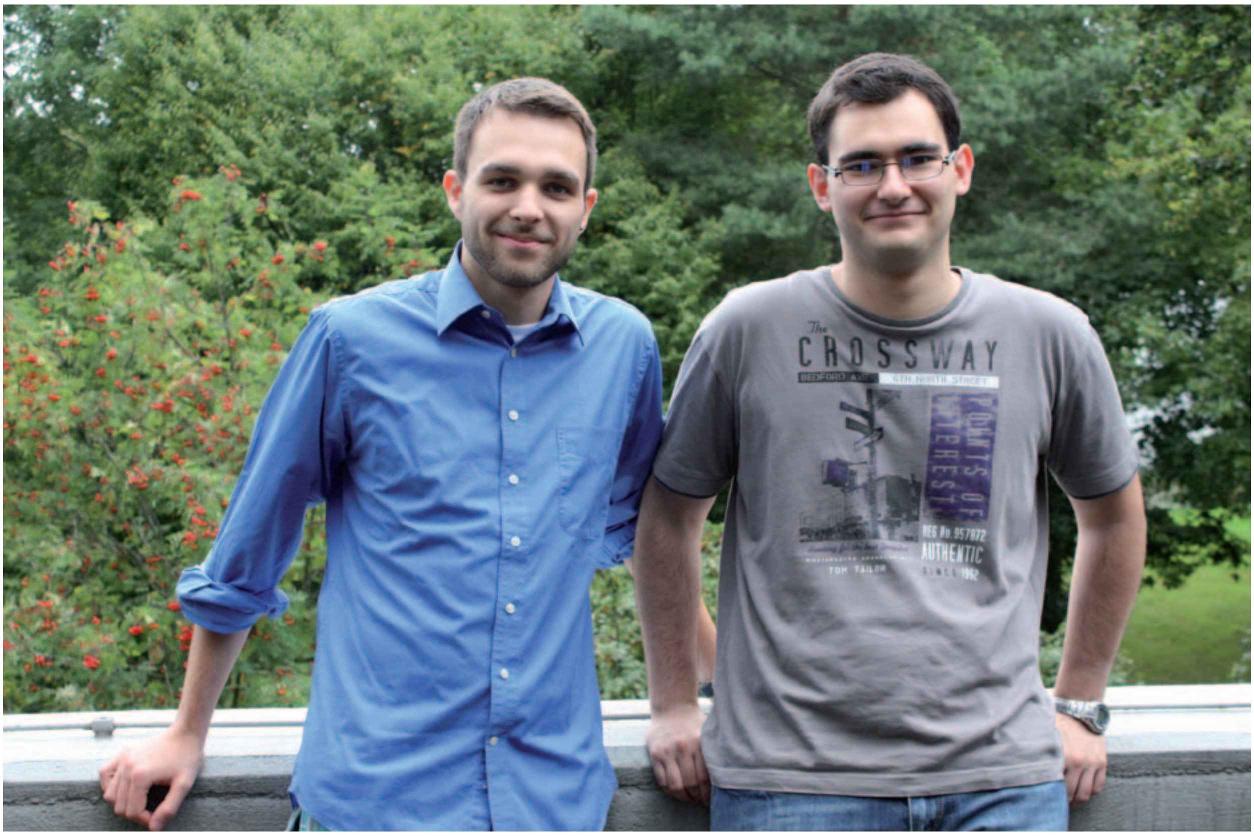
Fig. V.3.2: *Alexander Karim*

Fig. V.3.3: *Andreas Schruba*

Fig. V.3.4: *Olaf Fischer*

Fig. V.3.5: *Dimitrios A. Gouliermis*

Fig. V.3.6: *Fabian Wipfler und Marc-Oliver Lechner*



Andreas Schruba, postdoc at MPIA, for his paper "A molecular star formation law in the atomicgas-dominated regime in nearby galaxies" (2011, Astronomical Journal 142, 37).

As the years before, they were honored during the Patzer Colloquium which took place on December 2nd in the lecture hall of the MPIA where the prize winners gave a 30 minutes presentation of their work.

Further awards

Olaf Fischer from the Haus der Astronomie was awarded by the German Astronomical Society (Astronomische Gesellschaft, AG) during the annual meeting in Heidelberg in September 2011 with the *Hans-Ludwig Neumann Prize*. This prize was established in 1996 to recognize outstanding activities for the advancement of astronomy at school.

Dimitrios A. Gouliermis received the fellowships "Comprehensive Characterization with HST of Stellar Populations in Star-Forming Regions of the Large Magellanic Cloud" (DLR Program 50 OR 908) and "The Stellar Clusters Population of the Andromeda Galaxy from the Panchromatic HST Survey" (German Science Foundation (DFG) Program GO 1659/3–1).

Jouni Kainulainen, Hua-Bai Li, Sarah Ragan, Amy Stutz *und* ***Svitlana Zhukovska*** had been equipped with a research budget from the DFG Priority Program "Physics of the Interstellar Medium" while ***Dmitry A. Semenov*** received a research budget, also from the DFG, within the program "The first 10 million years of the Solar System – a Planetary Materials Approach" (SPP 1385)

Natalie Raettig received an Annette Kade Fellowship for a three months visit to the American Museum of Natural History (AMNH) in New York, USA, while ***Karin Sandstrom*** was awarded with a *Marie Curie International Incoming Fellowship*.

Since 2007 the Max Planck Society has been awarding up to 20 apprentices with the Apprenticeship Prize for excellent performance on the job and at school as well as for social involvement during the training period. For very good marks in his final year of training in the precision mechanics workshop of MPIA ***Fabian Wipfler*** received the Apprenticeship Prize for metal work as well as an award from the Chamber of Crafts Mannheim. The Apprenticeship Prize for administrative work went to ***Marc-Oliver Lechner*** who received his training in the MPIA administration department.

Klaus Jäger, Martin Kürster,
Axel M. Quetz

Staff

Directors: Henning (Managing Director), Rix

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

Scientists: Afonso, Andrae (since 1.9.), Bailer-Jones, Balog, Bertram, Betremieux (since 15.9.), Beuther, Bik, Birnstiel (until 30.6.) Borelli, Bouwman, Brandner, Brieva (since 1.10.), De Bonis, Deacon (since 1.10.), Decarli (since 1.2.), Döllinger (1.7. until 30.9.), Dullemond (until 31.8.), Dumas (until 15.3.), Dziourkevich (until 31.5.), Egner (parental leave), Feldt, Fendt, Fried, Gässler, Goldman, Gouliermis, Graser, Gredel, Hayfield (since 15.2.), Hennawi, Herbst, Hippler, Hofferbert, Ilgner (since 1.5.), Inskip (maternity protection and parental leave since 5.4.), Huisken, Jäger K., Jahnke, Kaltenegger, Klaas, Klahr, Köhler, Kreckel H. (since 15.9.), Kreckel K. (since 1.12.), Krause, Kürster, Launhardt, Leipski, Lenzen, Linz, Liu Chao, Macciò, Marien, Martin, Meisenheimer, Möller-Nilsson, Müller, F., Mundt, Nielbock, Pavlov, Peter, Petitdemange (until 30.9.), Pössel, Pott, Rodriguez, Sandor (until 31.8.), Sandstrom (since 1.10.), Scheithauer (parental leave until 14.4.), Schmiedeke (until 30.4.), Schinnerer, Schreiber, Seidel (since 15.2.), Semenov, Setiawan (until 30.9.), Sicilia-Aguilar (until 30.6.), K. Smith, Tabatabaei (since 1.3.), Trowitzsch, Tsalmantza, van Boekel, van de Ven (since 15.8.), Walter

Postdocs: Adamo (since 1.9.), Benisty, Bergfors (since 1.12.), Biller, Bonnefoy, Burtscher (since 1.6.), Chauvin, Cisternas (since 15.11.), Collins (since 15.9.), Commerçon (until 14.10.), Crighton, Da Cunha (since 1.3.), Decarli (until 31.1.), Dean (since 1.11.), Doellinger (until 30.6.), Fang Min (1.3. until 30.6.), Fanidakis (15.9.), Fedele (until 30.7.), Gennaro (since 1.12.), Gielen (until 31.8.), Groves, Hatt (until 15.7.), Hodge, Johnston, Kainulainen, Karovicova (since 15.8.), Kendrew, Krasnokutskiy, Kulkarni (since 1.10.), K. G. Lee, (since 15.9.2011, R. Lee (since 15.8.), H.-B. Li, Lusso (since 15.9.), Lyubenova, Mancini (since 1.5.), Martinez-Delgado, Meidt, Miguel (since 1.4.), Mordasini, Morganson, Nikolov (since 11.4.), Noel (until 30.9.), Olofsson, Ormel, Ragan, Rakic (since 1.11.), Rubin, Sandstrom (until 30.9.), Schlieder (since 1.9.), Schmalzl (1.2. until 31.3.), Schmidt T. (1.7.2011 until 31.8.), Stinson (since 1.7.), Stutz, Thalmann (until 9.1.), van den Bosch R., van der Wel, Venemans (since 15.9.), Wang Hsiang-Hsu (20.1. until 28.2.), Watkins, Xue (since 1.11.), Y. Yang, Zhukovska, Zimmerman (since 15.9.), Zsom

PhD Students: Albertsson, Arrigoni Battaia (since 1.10.), Banados Torres (since 1.9.), Bergfors (until 30.11.), Besel, Boley, Brangier (since 1.11.), Brasseur (until 7.5.), Büdenbender (since 1.5.), Caldu Primo (since 1.9.), Cielo (since 1.9.), Burtscher (until 26.5.), Chang Yu-Yen, Chang Jiang (since 1.10.) Chen Guo, Cisternas (until 14.11.), Cologna, Colombo, Csak (until 31.8.), De Rosa, Dittrich, Dittkrist (since 1.4.), Dopcke, Fang Min (until 28.2.), Feng Fabo (since 15.9.), Feng, Siyi (since 15.9.), Flock, Follert, Gennaro (until 30.11.), Gerner (since 1.4.), Hansson A. (1.10. until 31.12.), Hanson R. (since 1.10.), Hegde (since 1.4.), Golubov, Grootes, Holmes, M. Jäger, Jin (since 1.11.), Kalinova, Kannan, Kapala (since 1.10.), Karim (until 30.11.), Kurokawa (since 1.9.), Kudryavtseva, Läsker, L. Liu (until 30.9.), Lippok, C.-C. Lu, Ludwig, Maier, Malygin (since 1.11.), Manjavacas (since 15.10.), Micic (1.10. until 31.12.), Mohler, Müller, A. (since 1.3.), Nikolic, Nikolov (until 10.4.), Nugroho, Pang (1.9. until 30.11.), Paudel (until 31.3.), Penzo (since 1.9.), Pitann (until 30.11.), Porth (until 31.10.), Potrick, Raettig, Ramkumar, Rochau, Rorai, Ruhland (until 31.5.), Sabri, Schmalzl (until 31.1.), K. B. Schmidt, T. Schmidt (until 30.6.), Schnülle (since 1.7.), Schruba (until 30.11.), Schulze-Hartung, Sheiknezami (since 15.7.), Singh (since 1.10.), Steglich, Stepanovs (since 1.7.), Sturm, Sun (since 1.11.), Uribe (until 31.10.), Vaidya (1.8. until 31.10.), Tackenberg, Trifonov, Uribe, Valente, Van der Laan (until 30.11.), Vasyunina (until 31.1.), H.-H. Wang (until 19.1.), Windmark (until 31.8.), Z. Yan, P. Yang, Zechmeister (until 15.2.), L. Zhang, M. Zhang, X. Zhang

Diploma Students and Student Assistants (UH): Dittkrist (until 31.3.), Chira (14.3. until 31.8.), Hirsch (since 26.9.), Kopytova (since 27.5.), Molliere (11.4. until 11.7.), Pohl (1.4. until 31.8.), Shurkin (since 1.10.), Voggel (28.4. until 21.7.), Wouter (since 1.9.)

Diploma and Master Students (FH): Neumeier, Niemann, Panduro

Interns: Abel, Baldauf, Betzold (until 14.5.), Brezinski, Ehret, Euler (until 28.2.), Jentsch (until 14.4.), Kugler, Li (1.3. until 31.8.), Lechner, Leonhardt (11.7. until 5.8.), Neidig (until 28.2.), Neumeier, Niemann (until 28.2.), Omari (1.3. until 31.8.), Specht (since 1.9.), Till (since 1.9.), Wipfler (until 31.7.)

Student Assistants: Barboza (until 31.1.), Bihr (since 1.8.), Ciceri (since 11.7.), Dittkrist (until 31.3.), Fiedler (until 22.8.), Fraß (since 1.10.), Haude (since 1.5.), Maseda (since 15.8.), Morrison (until 30.6.), Neumeier (since 1.9.), Panduro, Schneider (until 12.12.)

Public Outreach / Haus der Astronomie: Pössel (Head), N. Fischer, O. Fischer, Liefke, A. Ludwig, (since 8.9.), Quetz, Schultz (since 8.9.), Scorza; trainees: Fraß (since 1.10.), Frommelt (until 31.5.), Haude (since 1.5.)

Technical Departments: Kürster (Head)
Mechanics Design: Rohloff (Head), Baumeister (Deputy), Blümchen (until 14.8.), Ebert, Huber, Münch, Rochau (since 1.8.), Schönherr (until 31.8.); Trainees, Student Assistants: Barboza (until 31.1.), Euler (until 28.2.)

Precision Mechanics Workshop: Böhm (Head), W. Sauer (Deputy), Heitz, Maurer, Meister, Meixner, Stadler; Trainees, Student Assistants: Abel, Baldauf, Brezinski, Ehret, Kugler (since 1.9.), Merx, Neidig, Specht (since 1.9.), Wipfler

Electronics: Wagner (Head until 31.10.), Mohr (Head since 1.11., Deputy until 31.10.), Ramos (Deputy since 1.11.), Adler, Alter, Bieler (until 30.9.), Ehret, Klein, Lehmitz, Mall, Ridinger, Wrhel; Trainees, Student Assistants: Jentsch (until 14.4.), Y. Li (1.3. – 31.8.), Niemann (until 28.2.), Neumeier, Omari (1.3. – 31.8.), Panduro

Instrumentations-Software: Briegel (Head), Storz (Deputy), Berwein, Borelli, Kittmann, Kulas (since 1.6.), Möller-Nilsson, Neumann, Pavlov, Trowitzsch

Engineering and Project Management: Marien (Head), Bizenberger (Deputy), Bertram, Brix (until 30.4.), Conrad, De Bonis, Gässler, Graser, Hofferbert, Laun, Mellein, Meschke, Naranjo, Peter

Administrative and Technical Service Departments:
Administration: Voss (Head); purchasing dept.: Wolf, Anders; finances dept.: Mantwill-Aue (since 1.7.), S. Schmidt, (until 30.4.), Anders, Enkler, Zähringer; staff dept.: Apfel, Baier, Hölscher, Scheerer (until 31.5.), Schleich; reception: Beckmann; trainees: Lechner, Leonhard (11.7. – 6.8.), Till (since 1.9.2011)

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 (maternity protection and parental leave since 21.9.), Seifert, Witte-Nguy

Technical Services and Cafeteria: F. Witzel (Head), Nauß (Deputy), Behnke, Drescher, Heller, Jung, Krämer (since 1.10.), Lang, B. Witzel, E. Zimmermann

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

Freelance Science Writer: Thomas Bührke

Guests: Santiago Barboza, Obs. Bordeaux, 1. Sep. 2010 – 31. Jan.; Neal Turner, Konkoly Obs., 6. Dec. 2010 – 7. March; Iva Karovicova, Univ. Salerno, 4. Jan.; Markus Janson, AIP, 9.–11. Jan.; Davide Fedele, Eso Garching, 10.–14. Jan.; V. Roccatagliata, 10.–14. Jan.; Claudio Llinares, Univ. Michigan, 11.–12. Jan.; Jens Zuther, Univ. Austin, 13.–14. Jan.; Thomas Ruppel, MPA, 18. Jan.; Else Starckenburg, CfA, 18.–19. Jan.; Matthew Horrobin, Eso Garching, 19. Jan.; Benjamin Weaver, IAS Cambridge, 22.–30. Jan.; Olia Panic, MPE, 24. Jan.–2. Feb.; Jonathan Menu, Eso Garching, 24.–25. Jan.; Steffi Walch, CEA/SACLAY, 24.–26. Jan.; Luigi Mancini, Univ. Bologna, 25.–28. Jan.; Natasha Madox, Leiden Obs., 25.–26. Jan.; Giuseppa Battaglia, Inst. Scien. Espai, 25.–26. Jan.; Olivera Rakic, Univ. Barcelona, 23.–25. Jan.; Stefan Kraus, Univ. Groningen, 25.–27. Jan.; Josh Adams, Harvard Univ., 26.–28. Jan.; Roderick Overzier, SRON Groningen, 26.–27. Jan.; Thomas Robitaille, Univ., 26.–28. Jan.; Pamela Klaassen, 27. Jan.; Ryan Cooke, Univ. Madrid, 27.–28. Jan.; Thomas Müller, Univ. Florida, 27.–28. Jan.; Bram Venemans, Univ. Cambridge, 27.–28. Jan.; Mark Sargent, Univ. Milano, 27.–28. Jan.; Elisabeta Lusso, Obs. Bordeaux, 29. Jan.; Eva Meyer, Leiden Observatory, 31. Jan.–4. Feb.; Andreu Font, Univ. Milano/Trieste, 1.–2. Feb.; Aday Robaina, Princeton, 6.–10. Feb.; Peter Barthel, Univ. Köln, 6.–9. Feb.; Joanna Kuraszkiewicz, IAC, 6.–9. Feb.; Max Avruch, IAC, 6.–9. Feb.; Luciano Casarini, CfA Harvard, 7.–19. Feb.; Sebastian Daemgen, Eso, Chile, 7.–11. Feb.; Jose Caballero, MPA Garching, 8.–11. Feb.; Mark Keremedjiev, Univ. California, 10.–13. Feb.; Michelle Colling, Black Bird Obs., 13.–14. Feb.; Luciano Casarini, Tokyo Inst. Techn., 7.–19. Feb.; Hincelin Ugo, Esa, 14.–18. Feb.; Joshua Schlieder, Praktikant, 8.–10. Feb.; Silvio Bonometto, LRA Paris, 14.–16. Feb.; Khee-Gan Lee, MPIfR Bonn, 21.–24. Feb.; Jens Zuther, MPIfR Bonn, 22.–24. Feb.; Agnieszka Rys, Sobolev Inst., 25. Feb.–12. March; Jesus F. Barroso, Konkoly Obs., 2.–4. March; Lars E. Hernquist, JPL, 5.–9. March; Emanuela Pompei, Stockholm Univ., 7.–11. March; Ben Moster, Univ. Hawaii, 7.–11. March; Imke de Pater, CfA, 13.–15. March; Jay Gabany, Leuven, 14.–17. March; Hiroyuki Kurokawa, UCLA, 14.–20. March; Torsten Böker, 14.–18. March; Roxana Chira, 15. March – 15. July; Patrick Hennebelle, 16.–17. March; Arnaud Belloche, STScI, 16.–17. March; Anastasi Tsitali, Univ. Bologna, 16.–17. March; Nikolai Voshchinnikov, Eso, 17. March – 14. Apr.; Csaba Kiss, Univ. Torun, 21.–23. March; Roger Lee, Univ. Torun, 21.–23. March; Angela Adamo, MPE, 22.–25. March; Nader Haghighipour, Leiden Obs., 27.–30. March; Thomas Robitaille, Russ. Acad. Sci., 28. March; Katrina Exter, Kapteyn Inst., 28. March; Heike Schlichting, Univ. California, 3.–4. Apr.; Brian Cobile, Kapteyn Inst., 4.–15. Apr.; Sabrina Nietzel, Ohio State Univ., 11.–15. Apr.; Paul Mollière, Ohio State Univ., 11. Apr.–6. July; Massimo Robberto, Konkoly Obs., 12.–14. Apr.; Camillo Penzo, Konkoly Obs., 13.–15. Apr.; Bram Venemans, Univ. Chile, 13.–14. Apr.; Joanna Drazkowska, Univ. Birmingham, 17.–22. Apr.; Kacper Kowalik, Univ. Göttingen, 17.–22. Apr.; Clare Dobbs, College Charleston, 18.–20. Apr.; Eva Meyer, Leiden Observatory, 26.–29. Apr.; Yaroslav Pavlyuchenkov, Univ. Zürich, 20. Apr.–12. May.; Mark den Brok, Csiro, 1. May – 31. July; Andreas Seifahrt, Univ. Lancashire, 3.–6. May; Marco Spaans, AifA, 4.–5. May; Anton Vasyunin, Durham Univ., 8.–29. May; Tatiana Vasyunina, Oss. Astron. Trieste, 8.–29. May; Csaba Kiss, MPE, 9.–11. May; Nikolett Szalai, Univ. Warsaw, 9.–11. May; Markus Rabus, UC Berkeley, 9.–14. May; Vinothini Sangaralingam, Ruhr Univ. Bochum, 10.–11. May; Mathias Zechmeister, Inaf, 10.–13. May; Joe Carson, IAA, 10. May – 10. June; Olja Panic, LBTO, 10. May – 10. June; Silvia Garbari, LBTO, 12.–13. May; Maxim Voronkov, Raytheon, 11.–13. May; Greg Stinson, Univ. Toronto, 12.–17. May; Vernesa Smolcic, Groningen Univ., 15.–19. May; Nikos Fanidakis, University Toledo, 16.–20. May; Fabio Fontanot, Eso, 16.–20. May; Marc Schartmann, Harvard Univ., 18. May; Maria Kapala, Univ. Zürich, 26.–27. May; Frank Bigiel, Univ. Mexico, 27.–28. May; Rolf Chini, PSU, 30. May; Alessandro Brunelli, Univ. Wyoming, 30. May – 10. June; Conchi Cardenas, Univ. Maryland, 30. May – 10. June; Dave Thompson, Inaf, 30. May – 10. June; Tim Shih, Inaf, 30. May – 10. June; Andrew Dolphin, UC Santa Cruz, 5.–12. June; Markus Janson, Oss. Catania, 6.–9. June; Marten Breddels, LMU, 6.–17. June; J.D. Smith, Boulder, 6. June – 4. Aug.; Andreas Glindemann, IPMU Tokyo, 8.–9. June; Rebekah Dawson, Univ. Washington, 9.–10. June; Ros Roskar, UC Santa Cruz, 9.–10. June; A. Segura Peralta, Univ. Victoria, 9. June – 22. July; Alexander Wolszczan, UC Santa Cruz, 10. June – 12. July; Adam Myers, MIT, 10. June – 10. Aug.; Alberto Bolatto, Univ. Kansas, 13.–16. June; Antonella Natta, Eso, 15. June – 15. July; Malcolm Walmsley, UCO/Lick Obs., 15. June – 15. July; Jason Prochaska, Univ. California, 15. June – 31. Aug.; V Antonuccio-Delogu, Univ. Washington, 16. June – 25. July; Maria Lenius, Steward Obs., 20.–21. June; Glen Stewart, NYU, 21.–22. June; John D. Silverman, CAS, China, 22.–25. June; Julianne Dalcanton, JHU, 23. June – 21. July; Gabor Worseck, StSI, 24. June – 24. July; Aaron Dutton, NYU, 25. June – 9. July; Michele Fumagalli, NYU, 26. June – 2. July; Rob Simcoe, Univ. Cape Town, 27. June – 22. July; Greg Rudnick, Univ. Budapest, 27. June – 28. July; Olja Panic, Imperial Coll. London, 27. June – 8. July; Connie Rockosi, Harvard Univ., 27. June – 9. July; Brad Holden, Univ. Utah, 27. June – 9. July; Dan Weisz, Keck Obs., 28. June – 26. July; Benjamin Weiner, Univ. Utah, 29. June – 1. Aug.; Jo Bovy, IAA, 29. June – 4. Aug.; Jifeng Liu, Univ. Amsterdam, 30. June – 1. July; Davide Fedele, CfA, 4.–30. July; Veronica Roccatagliata, Konkoly Univ., 4.–30. July; Lang Dustin, CfA, 2. July – 2. Aug.; David Hogg, New York University, 2. July – 1. Sep.; Erwin De Blok, Oxford Univ., 1.–31. July; Victor L. Toth, IAA, 1. July – 31. Aug.; Sami Dib, OAN, 4.–15. July; Dimitar Sasselov, Univ. Milano, 1.–8. July; Adam Bolton, Arcetri, 2.–15. July; Randy Campbell, Inaf, 4. July; Joel Brownstein, Iram, 5.–15. July; Rainer Schödel, UC Santa Cruz, 5.–7. July; Gijs Mulders, Nagoya Univ., 5.–8. July; Martin Elvis, UC Santa Cruz, 9.–16. July; Peter Abraham, Univ. Kyiv, 4.–8. July; Giuseppina Fabbiano, 10.–16. July; Khee-Gan Lee, 10.–17. July; Sownak Bose, Harvard Univ., 11.–30. July; Cardenas Conceipcion, JPL, 12.–22. July; Santiago Garcia-Burillo, NYU, 17.–22. July; Massimo Dotti, Inaf, 17.–24. July; Carmelo Arcidiacono, 18.–22. July; Alessandro Brunelli, Univ. Ukraine, 18.–22. July; Jerome Pety, Lawrence Nat. Lab., 18.–22. July; Jessica Werk, Haverford College, 18.–27. July; Satoshi Okuzumi, Inst. Uzbekistan, 18.–29. July; Robert Da Silva, Univ. California, 18. July – 1. Aug.; Mykola Malygin, Obs. Strasbourg, 24.–29. July; David Cann, Herzberg Inst., 25. July – 11. Aug.; Emma Wolpert, JPL, 25. July – 11. Aug.; Sarah Rugheimer, McGill Univ., 29. July – 26. Aug.; Pieter Deroo, Drexel Univ., 31. July – 14. Aug.; Dan Foremann-Mackey, Univ. Victoria, 1.–26. Aug.; Carmelo Arcidiacono, UC Santa Cruz, 1.–5. Aug.; William Fischer, Chin. Acad. Sci., 1.–5. Aug.; Nao Suzuki, Inst. Astron. RAS, 14.–20. Aug.; Ross Fadely, Univ. HD, 15.–25. Aug.; Mansur Ibrahimov, Inaf, 15.–28. Aug.; Steven Beckwith, MPIfR Bonn, 21.–25. Aug.; Caroline Bot, Herzberg Inst., 23.–24. Aug.; Cassandra Fallcheer, Groves, 29. Aug.–9. Sep.; Mark Swain, Univ. College London, 3.–12. Aug.; Gabriel-D. Marleau, Univ., 8.–12. Aug.; Gordon Richards, Univ. Pisa, 8.–31. Aug.; Trevor Mendel, Univ. Amsterdam, 9.–13. Aug.; Gabor Worseck, Univ. Toledo, 9.–28. Aug.; Wang Wei, CSIC-IEEC, 1.–30. Sep.; Kevin Flaherty, IAC, 4.–7. Sep.; Vitaly Akimkin, Tata Inst. Pune, 5.–18. Sep.; Maria Knodt, Univ. Victoria, 5.–30. Sep.; Riccardo Smareglia, Univ. Wisconsin, 5.–9. Sep.; Konrad Tristram, 8.–9. Sep.; James Di Francesco, Obs. Paris, 9.–17. Sep.; Patrik Jonsson, Inasan, 12.–16. Sep.; Steve Boudreault, 15.–20. Sep.; P.G. Prada Moroni, ATC Edinburgh, 18.–24. Sep.; Emanuele Tognelli, Inst. TP, Zurich, 18.–24. Sep.; Gerrit van der Plas, Inst. TP, Zurich, 19.–23. Sep.; William Fischer, NRAO, 25.–28. Sep.; Marco Padovani, Inasan Moscow, 26. Sep.–31. Oct.; Agnieszka Rys, Ipag/CNRS, 29. Sep.–12. Oct.; Sambit Roychowdhury, Ipag/CNRS, 1.–5. Oct.; Ryan Leaman, MPE, 1.–9. Oct.; Jay Gallagher, Lab. Marseille, 7. Oct.; Carol Grady, Yonsei Univ., 7. Oct.; Matthieu Brangier, yonsei Univ., 9.–12. Oct.; Vitaly Akimkin, CfA, 9.–30. Oct.; Sin-iti Sirono, Dark Cosm. Inst., 10.–11. Oct.; Adrian Glauser, Insugeo-Conicet, 10.–13. Oct.; Donnino Anderhalden, Eso, 10.–14. Oct.; Aurel Schneider, Univ. Como, 12.–14. Oct.; Jürgen Ott, KU Leuven, 21.–29. Oct.; Y. Pavlyuchenkov, Univ. Edinburgh, 24. Oct.–6. Nov.; Xavier Bonfils, Univ. Oxford, 26.–28. Oct.; David Ehrenreich, IAA, 26.–28. Oct.; Thomas Müller, MPA Garching, 2.–4. Nov.; Clement Surville, Inst. Astrophy. Paris, 7.–11. Nov.; Hyun-Jin Bae, IAA, 7.–8. Nov.; Hyun-Jin Bae, DAMTP Cambridge, 7.–8. Nov.; Dae-Won Kim, IAA, 7.–9. Nov.; Andrew Zirm, Univ. Leiden, 9.–13. Nov.; Olga Pintado, Univ. Madrid, 11.–19. Nov.; Andreas Glindemann, NRAO, 14. Nov.; Emanuele P. Farina, University of Insubria, 14.–18. Nov.; Jonathan Menu, Iram, 14.–18. Nov.; Adrian Glauser, AEI, 14.–18. Nov.; Yixiong Wang, Eso, 20.–22. Nov.; A. Segura, Harvard Cfa, 20.–25. Nov.; Ben Moster, 21.–23. Nov.; Camilla Pacifici, ETH, 21.–25. Nov.; Jose M. Ibanez, Univ. California, 21.–25. Nov.; Sijme-J. Paardekooper, Caltech, 21.–26. Nov.; Matilde Fernandez, Univ. Hertfordshire, 25. Nov.; Simone Weinmann, 25.–26. Nov.; Chris Brook, 27. Nov.–1. Dec.; John Tobin, 27. Nov.–3. Dec.; Michele Fumagalli, 6.–9. Dec.; Pierre Cox, 7.–8. Dec.; Felicitas Mokler, 8.–16. Dec.; Mark Westmoquette, 12.–13. Dec.; Sijacki Debora, 14. Dec.; Peter Hofner, 14.–16. Dec.; Adrian Glauser, 14.–16. Dec.; Steve Beckwith, 14.–18. Dec.; Dominik Richers, 18.–21. Dec.; Elias Brinks, 18.–23. Dec.

Short-term Scholarships: Antonuccio (14.6. until 27.7.), Burtscher (1.6. until 31.12.), Dalcanton (23.6. until 21.7.), El-Kork (27.6. until 06.8.), Fedele (3.7. until 30.7.), Jin (1.12.), Kostogryz, Main Astronomical Observatory of NAS of Ukraine (1.8. until 30.9.), Lang (2.7. until 02.8.), Natta (15.6. until 15.7.), Panic (15.5. until 30.6.), Pavlyuchenkov (15.4. until 14.5.), Richards (1.8. until 31.8.), Roccatagliata (3.7. until 30.7.), Segura (1.7. until 31.7.), Simcoe (27.6. until 29.7.), Smith (6.6. until 04.8.), Toth (1.7. until 31.8.), Walmsley (15.6. until 15.7.), Wang Wei (1.9. until 30.9.), Weaver (1.1. until 04.2.), Weisz (28.6. until 26.7.)

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

Calar Alto Observatory Almeria, Spain

Astronomy Coordination: Thiele
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, Rory Holmes, Ulrich Klaas, Hendrik Linz, Friedrich Müller, Markus Nielbock, Jan Pitann, Silvia Scheithauer, Anika Schmiedeke, Jürgen Schreiber, Amy Stutz

Star Formation: Henrik Beuther, Angela Adamo, Tobias Albertsson, Miriam Benisty, Adrianus Bik, Paul Boley, Miwa Egner (parental leave), Min Fang, Markus Feldt, Siyi Feng, Mario Gennaro, Thomas Gerner, Dimtrios Gouliermis, Katharine Johnston, Jouni Kainulainen, Ralf Launhardt, Roger Lee, Huabai Li, Rainer Lenzen, Nils Lippok, Maria Elena Manjavacas Martinez, Johan Olofsson, Sarah Ragan, Boyke Rochau, Markus Schmalzl, Dmitri Semenov, Aurora Sicilia Aguilar, Bernhard Sturm, Jochen Tackenberg, Roy van Boekel, Antonin Vasyunin, Tatiana Vasyunina, Wei Wang, Yuan Wang, Miaomiao Zhang, Svitlana Zhukovska

Brown Dwarfs/Exoplanets: Reinhard Mundt, Carolina Bergfors, Beth Biller, Mickaël Bonnefoy, Wolfgang Brandner, Gael Chauvin, Guo Chen, Michaela Döllinger, Bertrand Goldmann, Felix Hormuth, Sarah Kendrew, Rainer Köhler, Natalia Kudryavtseva, Luigi Mancini, Maren Mohler, Victoria Rodriguez Ledesma, Tim Schulze-Hartung, Johny Setiawan, Zhao Sun, Christian Thalmann, Matthias Zechmeister, Neil Zimmerman

Theory (SP): Hubertus Klahr, Hassnat Ahmad, Bennoit Commerçon, Karsten Dittrich, Natalia Dziourkevitch, Mario Flock, Mykola Malygin, Christoph Mordasini, Ludovic Petitdemange, Nathalie Raettig, Ana Uribe

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

Frontiers of Interferometry in Germany (FrInGe): Thomas Henning, Uwe Graser, Rainer Köhler, Ralf Launhardt, Roy van Boekel

Adaptive Optics: Wolfgang Brandner, Guo Chen, Casey Dean, Markus Feldt, Dimitrios Gouliermis, Stefan Hippler, Felix Hormuth, Natalia Kudryavtseva, Christian Thalmann, Pengqian Yang

MPG Junior Research Group: Cornelis Dullemond, Tilmann Birnstiel, Martin Ilgner, Christian Ormel, Paola Pinilla, Zsolt Sandor, Fredrik Windmark, Andras Zsom

MPG Junior Research Group: Thomas Robitaille

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

Emmy-Noether-Group: “Charakterisierung extrasolarer Planeten”: Lisa Kaltenegger, Yan Yves Betremieux, Yamila Miguel, Siddarth Hegde, Hiroyuki Kurokawa

Department: Galaxies and Cosmology

Director: Hans-Walter Rix

Milky Way and Local Group: Coryn Bailer-Jones (inclusive the GAIA project group), René Andrae, Fabo Feng, Richard Hanson, Chao Liu, Kester Smith, Paraskevi Tsalmantza, Thomas Herbst, Hans-Walter Rix, Christal Brasseur, Michel Collins, Nicolas Martin, David Martinez-Delgado, Christine Ruhland, Xiangxiang Xue

Galaxies in the present Universe: Andrea Macciò, Eva Schinnerer, Sharon Meidt, Dario Colombo, Tessel van der Laan, Glen van de Ven, Greg Stinson, Rahul Kannan, Mariya Lyubenova, Vesselina Kalinova, Roland Laesker, Sladjana Nikolic, Robert Singh

Galactic Center and Black Holes: Christian Fendt, Joseph Hennawi, Knud Jahnke, Katherine Inskip, Dading Hadi Nugrohu, Klaus Meisenheimer, Leonard Burtscher, Jörg-Uwe Pott, Iva Karovicova, Kirsten Schnuelle

The interstellar and intergalactic Medium: Joseph Hennawi, Eva Schinnerer, Gael Dumas, Brent Groves, Jacqueline Hodge, Annie Hughes, Kathryn Kreckel, Fatemeh Tabatabaei, Fabian Walter, Anahi Caldu Primo, Elisabetha da Cunha, Maria Kapala, Eric Morganson, Karin Sandstrom, Andreas Schruba, Hsiang-Hsu Wang

Galaxy Evolution and the early Universe: Knud Jahnke, Mauricio Cisternas, Gregor Seidel, Klaus Meisenheimer, Michael Fiedler, Mathias Jäger, Christian Leipski, Hans-Walter Rix, Kasper Borello Schmidt, Yu-Yen Chang, Michael Maseda, Balasubramanian Ramkumar, Arjen van der Wel, Eva Schinnerer, Alexander Karim, Fabian Walter, Eduarodo Banados Torres, Roberto Decarli, Gisella de Rosa, Bram Venemans

Galaxy Dynamic: Hans-Walter Rix, Lan Zhang, Glenn van de Ven, Remco van den Bosch, Laura Watkins, Alex Büdenbender

Numerical and Cosmological Simulations: Christian Fendt, Oliver Porth, Somayyeh Sheiknezami, Deniss Stepanovs, Barghav Vaidya, Joe Hennawi, Neil Crighton, Girish Kukarni, Khee-Gan Lee, Elisabeta Lusso, Olivera Rakic, Kate Rubin, Yujin Yang, Fabrizio Arrigoni Battaia, Gabriele Maier, Alberto Rorai, Andrea Macciò, Jian Chang, Salvatore Cielo, Nikolaos Fanidakis, Camilla Penzo

Instrumentation Development: Thomas Herbst, Michael Boehm, Matthieu Brangier, Jian Chang, Roman Follert, Qiang Fu, Eva Meyer, Joshua Schlieder, Zhaojun Yan, Xianyu Zhang, Josef Fried, Jörg-Uwe Pott

Teaching Activities

Winter Term 2010/2011

Chr. Fendt, C. Dullemond, J. Hennawi: IMPRS (Seminar)
Th. Henning, H. Beuther: Star Formation (Lecture)
S. Hippler: Experiment F36 "Wave Front Analysis", Advanced Practocal for Physicists (Practicals)
V. Joergens, H. Klahr: Extrasolar Planets and Brown Dwarfs (Lecture)
H. Klahr, R. Mundt: Einführung in die Astronomie und Astrophysik III (Seminar with J. Heidt and J. Krautter)
K. Meisenheimer: Institute Colloquium of MPIA and LSW (Colloquium with S. Wagner)
H.-W. Rix: Galaxies (Course Lecture, block course), Exercises on Galaxies (Exercise)

Summer Term 2011:

H. Beuther, Chr. Fendt: Outflows and Jets: Theory and Observations (Lecture)
R. van Boekel: Observational Astronomy (Lecture with A. Quirrenbach (LSW) und C. Dullemond (ITA))
C. Dullemond: Observational Astronomy (Course Lecture)
Chr. Fendt, C. Dullemond, J. Hennawi, V. Joergens: Seminar on current research topics (IMPRS 1) (Seminar)
Chr. Fendt: Astronomy for Non-Physics (with A. Just (ARI))
Th. Henning: Physics of Star formation (Master-Pflichtseminar)
S. Hippler: Experiment F36 "Wave Front Analysis" of the Advanced Practocal for Physicists (Practicals)
F. Huisken, C. Jäger: Cluster & Nanoteilchen II, Friedrich Schiller Universität, Institut für Festkörperphysik, Jena
K. Jahnke: Gruppenunterricht zur Experimentalphysik II (Exercise)
V. Kalinova: Experiment FP 30 "CCD photometry with 70-cm telescope" of the Advanced Practocal for Physicists (Practicals)
L. Kaltenegger: IMPRS summer school: Characterizing exoplanets – from formation to atmospheres (with W. Benz (Univ. Bern), P. Hauschildt (Univ. Hamburg), A. Johansen (Lund Observatorium), S. Udry (Observatorium Genf))
H. Klahr: Advanced seminar on Theory of Planet and Star Formation (Seminar)
H. Klahr, Chr. Mordasini: Physics and Numerics of Accretion Disks and Planet Formation (Lecture)
H. Klahr, V. Joergens: Extrasolar Planets and Brown Dwarfs (Lecture)
R. Köhler, A. Müller: Introduction to IDL for Scientific Research (block course)
K. Meisenheimer: Gruppenunterricht zur Experimentalphysik II (Exercise)

H.-W. Rix: Galaxy Coffee (Advanced Seminar), Galaxies (Lecture)

H.-W. Rix, F. Walter, N. Martin: Galaxies (block course)

Winter Term 2011/2012:

H. Beuther, H, Klahr, H.-W. Rix: Einführung in die Astronomie und Astrophysik III (Pflichtseminar)

C. Dullemond: Numerische Gas- und Flüssigkeitsdynamik (Lecture / Exercise), Mathematische Methoden in der Physik I (Lehramt) (Lecture / Exercise)

C. Dullemond, J. Hennawi: Cosmology (Lecture / Exercise / Seminar)

Chr. Fendt, K. Meisenheimer, G. Van de Ven: Seminar zu aktuellen Forschungsthemen (IMPRS 1) (mit R. Klessen (ITA), S. Glover (ITA), A. Koch (LSW))

Th: Henning: Physik der Sternentstehung (Advanced Seminar)

S. Hippler: Experiment F36 "Wave Front Analysis", Advanced Practocal for Physicists (Practicals)

V. Joergens: Extrasolare Planeten und Braune Zwerge (Lecture / Seminar)

H. Klahr: Numerisches Praktikum (Practicals), Physik und numerische Methoden zu Akkretionsscheiben und Planetenentstehung (Lecture)

H. Klahr, Chr. Mordasini: Uknum Numerical (Seminar)

K. Meisenheimer: Institute Colloquium of MPIA and LSW (Colloquium with S. Wagner)

Service in Committees

Coryn A. L. Bailer-Jones: Member of the "PhD-Students Advisory Committee" at the MPIA; Manager of the Subconsortium "Astrophysical Parameters", Gaia Data Processing and Analysis Consortium; Member of the Gaia Data Processing and Analysis Consortium Executive

Henrik Beuther: Member of the Iram program committee; Member of the Apex MPG program committee; Member of the Patzer foundation board

Karsten Dittrich: Student Representative; Head of the Event-Gruppe (PhDnet)

Christian Fendt: External reviewer and auditor of the PhD student Noemie Globus, Laboratoire de L'Univers et ses theories, Paris, France

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 Calar Alto Time Allocating Committee (TAC); Member of the Linc-Nirvana Science Team

Roland Gredel: Member of der ELT science and engineering group; Member of the CTA internal site assessment; Chair of the LBT internal operational readiness review; Chair of the LBT time domain observations working group; Chair of the Opticon board; Member of der Opticon committees "telescope directors forum", "enhancement activities Eastern Europe" and "NEON summer schools"; Chair of the Stac; Chair of the Linc-Nirvana internal review committee.

Thomas Henning: Member of the Eso Council; Chair of the LBT associated company; Member Representative of the LBT Board; Member of the Caha Executive Committee; Member of the Board of IAU Division VI, Interstellar Matter; Member of the National Cospar Committee; Representative of the Astronomy/ Astrophysics Subdivision of the Leopoldina; Member of the scientific committee of the Thüringer observatory Tautenburg; Member of der Appeal Committee of Dutch Academy Professorship Programme; Head of the ERC Panel for Advanced Grants PE9, "Universe Science"; Member of the Prize Committee of the Stern-Gerlach Award; Member of der Master Commission of the MPI für Chemie, Mainz; Member of der Appeal Committee for Professor of Astrophysics of the University of Innsbruck; Member of the Organizing Committee of the DFG Priority Programme "Physics of the Interstellar Medium"

Cornelia Jäger: Member of the Program Committee of the DFG priority program "The Physics of the Interstellar Medium"; Member of the Plenary Members Group of the EU Initial Training Network (ITN) "Lassie – Laboratory Astrochemical Surface Science in Europe"

Klaus Jäger: board member of the Astronomische Gesellschaft (Press Officer); Member of the scientific advisory committee of the International Summer Science School Heidelberg (ISH); Participation in the Rat Deutscher Sternwarten (RDS); Participation in the LBT-associated company (LBTB)

Lisa Kaltenegger: Member of the Editorial boards of the series of books "Astrobiology", at Springer Astrobiology and at the Encyclopedia of Astrobiology, Member in boards of Nasa, NSF, Royal Society review panels, DFG, French Academie of Science, Exobiology, LBT, Kepler, Astrobiology; Member of the PAC; Member of the Executive Council, Nasa Extrasolar Planet Analysis Group

Oliver Krause: Member of the Esa-EChO Science Teams

Martin Kürster: Member of the Espresso PDR Review Board

Ralf Launhardt: Member of the S-TAC at the MPIA; Member of the ERC starting grants evaluation panel

Christoph Leinert: Member of the Eso OPC panels; Member of the International Advisory Board of the Konkoly Observatory

Hua-Bai Li: Member of the Expert committee for the award of Discovery Grants of the Natural Sciences and Engineering Research Council of Canada

Nicholas Martin: Member of the Next Generation Canada-France-Hawaii Telescope Science Working Group; Head of the Pan-Starrs1 Science Consortium Key Project 5 (the Milky Way and the Local Group)

Klaus Meisenheimer: Member of der AGN/Galactic Center working group

Reinhard Mundt: Member of the CARMENES Core Managment Team as Representative of the MPIA; Ombudsman of the MPIA

Markus Nielbock: Member of the HERSCHEL PACS Instrument Control Centre (ICC); Member of the HERSCHEL Calibration Steering Group as a Representative of the PACS ICC; Member of der HERSCHEL Pointing Working Group

Hans-Walter Rix: Member of the PS1 Science Consortium; Member of the NIRSPEC Science Team; Member of the DFG boards; Member of the Emmy-Noether Panel; Member of the Visiting Committees STScI; Member of the EUCLID Mission Board

Eva Schinnerer: Member of the NRAO Users Committee

Amelia Stutz: Member of the MPIA STAC; Member of the ESO TAC

Roy van Boekel: Member of the belgium VLTI TAC

Glenn van de Ven: Member of the LINC-NIRVANA Science Team

Remco van den Bosch: Member of the MPIA computer committee

Tessel van der Laan: Member of the WBK

Fabian Walter: Member of the NRAO Panel to Advise on Science and EVLA Operations (Paseo)

Further Activities

The MPIA released 12 press releases. Several radio and television interviews have been given (Klaus Jäger, Markus Pössel, Axel M. Quetz, and others).

The eight lectures of the lecture series "Astronomie am Sonntag Vormittag" in June and July have been organized by Markus Pössel, Klaus Jäger, and Axel M. Quetz.

Markus Feldt organized the "Miniforschung" for undergraduates.

For the Girls' Day on April 14th at the institute Vianak Naranjo was responsible, with participation of Klaus Jäger, Markus Pössel, Lisa Kaltenegger, Natalie Raettig, Aurora Sicilia, and others.

The Board of Trustees hold a meeting on November 29th which was organized by Klaus Jäger, Thomas Henning, and Hans-Walter Rix.

The pupil practical "Astronomie" on October 24. – 28. was organized and led by Klaus Meisenheimer and Michael Biermann (ZAH / LSW) with participation of Silvia Scheithauer, and Klaus Jäger.

During the year a total of 440 visitors in 19 groups have been given guided tours through the institute (Axel M. Quetz, Markus Pössel, Vesselina Kalinova, Silvia Scheithauer, and others).

The new newsletter of the MPIA was elaborated by Klaus Jäger (conception and editing work), Mathias Voss, Thomas Henning, and Hans-Walter Rix.

In honor of Jakob Staude on November 15 a scientific celebratory colloquium was held, organized by Klaus Jäger, Markus Pössel, Axel M. Quetz, and Hans-Walter Rix.

Vianak Naranjo held the office of the equal opportunities officer at the MPIA.

Tessel van der Laan (until Sept. 29), Karsten Dittrich (since Sept. 29) and Maren Mohler have been student representatives at the MPIA during 2011.

Axel M. Quetz was member of the editorial team which created the 50th volume of "Sterne und Weltraum". Jakob Staude was member of the publisher team of the 50th volume of "Sterne und Weltraum".

Guided tours through the Astrophysical Laboratory in Jena during the "Long night of the Sciences" on November 25th under the motto "Laboratory experiments simulate conditions in interstellar dust clouds" were held by Cornelia Jäger, Gaël Rouillé, Karsten, Potrick, and Mathias Steglich.

Roberto Decarli organized the weekly Galaxy Coffee.

Brent Groves was science co-coordinator of the KINGFISH group.

Friedrich Huisken was member of the program commitee of the international conference: International Symposium on Rarefied Gas Dynamics (RGD) and Mitheraco-editor of the Romanianen conference series on laser and optics "ROMOPTO".

Klaus Jäger created contributions for TV broadcaster (ARD, SWR, RNF, N24, CampusTV) as well as counseled them; he created contributions für print magazines; he created an audio/video trailer for the opening of the Astronomischen Gesellschaft (AG) in Heidelberg; he composed and produced music on occasion of the inauguration of the "House of Astronomy" and for TV at astronomical topics; he wrote press releases for the AG, for the Rat Deutscher Sternwarten and the LBT-associated company (LBTB); he contributed in planning and on events of the "House of Astronomy", the International Science School Heidelberg, der annual meeting of the AG in Heidelberg and he gave several special guided tours and lectures; he organized the "Visitor Colloquium" at the MPIA (with Meidt, Klahr).

Lisa Kaltenegger: collaboration with the ESA proposal teams of NEAT and EChO; PI of the ISSI-Team "1D/3D Exoplanet Atmospheres and their Characterization"; Co-I of the NASA Explorer Mission TESS; Co-I of the NASA Astrobiology Institute: Advent of Complex Life.

Alexander Karim took part at the science slam in Bonn with his contribution "Stars, Sterne und Galaxien" as well as at the science slam in the cinema "Capitol" in Mainz. He counseled the TV broadcaster 3Sat for the broadcasting "Für meine Forschung werben – auf der Bühne".

Ralf Launhardt was project scientist at Espri.

Dietrich Lemke war associated editor of the “Journal of Astronomical Instrumentation” (World Scientific). He wrote the book “Im Himmel über Heidelberg” on the occasion of the 40th anniversary of the MPIA. The book was presented with represantativs of the archive of the MPG (Berlin) to the public at a ceremonial act on May 23rd.

Hendrik Linz was guest scientist at the NRAO in Socorro, New Mexico, USA.

Markus Nielbock contributed on the “Tag der Astronomie 2011” at the Engadiner Astronomiefreunde in St. Moritz, Switzerland. He is member of the Astronomieschule e.V., Heidelberg.

Sarah Ragan was postdoc representative at the MPIA.

Kasper Borello Schmidt organized the monthly Heidelberg discussion forum on gravitation lenses “LiHD – Lensing in Heidelberg”.

Referees at Science Journals: Coryn A. L. Bailer-Jones (ApJ, A&A, MNRAS); Henrik Beuther (A&A, ApJ, MNRAS, Nature); Elisabete da Cunha (A&A); Friedrich Huisken (Advanced Materials, Nanotechnology, Science, NanoLetters, Applied Physics Letters, Journal of Applied Physics, Chemical Physics Letters, Chemical Reviews, Journal of Chemical Physics, Journal of Physical Chemistry, Journal of Nanoparticle Research, Computational Materials Science); Viki Joergens (Astrobiology, Icarus, ApJ, A&A, ApJL, PPS, Springer); Oliver Krause (ApJ, Nature); Hendrik Linz (ApJ).

Referee for Research Grants: Henrik Beuther (DFG, ERC National French Agency of Research); Christian Fendt: Externer Gutachter für Forschungsmittel des “Natural Sciences and Engineering Research Council of Canada”, FWO, Foundation for Scientific Research Belgium; Friedrich Huisken (DFG, EU (Marie-Curie), Fonds zur Förderung der wissenschaftlichen Forschung in Österreich, der Grant Agency of the Czech Republic, der Nasa, dem American Chemical Society Petroleum Research Fund, der German Israeli Foundation for Scientific Research and Development.

Compatibility of Science, Work, and Family

To present informations and solutions for better compatibility of job and family was in 2011 again an important matter to the MPIA. The institute supports men and women in all cases equaly. Main focus was set on the following domains:

1. Flexibility on the working environment:

Flexible configuration of the working hours is a fundamental premise for a better compatibility of job and family and an important aspect for scientists and other employees, who wants to bring their job in harmony with child care, care-dependent relatives or job related change of residence of the life partner. The MPIA supports different models or working. A flexible working environment is offered at the MPIA for both scientific as well as non-scientific employees. This includes family induced time-outs, temporary reduction of the working hours, or, if necessary, the flexible choice of the job location, for example at the home office.

2. Care services for employees with children and care for needy families:

The MPIA has together with the other Heidelberg MPIs access to a total of 21 nursery and kindergarten places. The MPIA cooperates with the MPI for Nuclear Physics for the rapid implementation of a kindergarten. The institute provides in-house support and a baby office for employees with breastfeeding children. In exceptional cases or emergency situations, employees may come to work with children. The international office offers advice in finding suitable places in nurseries, kindergartens and schools and in holiday childcare. The MPIA also provides support for employees with care-dependent relatives through the family service “Besser betreut” and via the information portal of the “Bündniss für Familie”.

3. Information portal at MPIA:

The information portal of the MPIA includes an e-mail list for parents and for employees with caring responsibilities for relatives. Here you find assistance, tips, suggestions and answers. Additional information on dual-career issues, including a dual-career job board can be found also on the related web pages of the institute at http://www.mpia.de/Public/menu_q2.php?MPIA/jobs/dualcareer.html. Related posts in the institute offers an information board with current postings. In family-related downtime employees may – if desired – stay connected via a contact retention program and attend training events, staff meetings and other important meetings.

4. Informationen for leaders:

When recruiting staff the service offerings of the Institute on “combatibility of work and family” in employment negotiations are integrated. Executives at MPIA know the people to contact about work and family issues, as well as dual-career work-life balance and can refer as needed to the appropriate contact person. By the end of 2011 the subject “awareness and involvement of leaders” in the working group “work and family” was selected in the Heidelberg alliance as main topic. A cross-enterprise information sharing has been started and will be continued and deepened in 2012.

5. Cooperation of the MPIA in networks:

The topic of networking is becoming increasingly important. The MPIA cooperates in the following networks for the implementation of solutions • Dual career network

Heidelberg: The dual career services at MPIA supports to help launch dual-career couples in furthering the career of the partner. In cooperation with the Heidelberg University, the University Hospital, the German Cancer Research Center (DKFZ), the European Molecular Biology Laboratory (EMBL), the SRH-Holding, the College of Education, the city of Heidelberg and the other Heidelberg MPIs, the dual career service provides contacts with potential employers in the region of Heidelberg and her support in the search for suitable locations. The dual career network has established an active job board with current vacancies and job applications. • Child Care Working Group of the University of Heidelberg: From this working group has resulted a cooperation agreement and rights for several places in a kindergarten were ascertained. • The MPIA is a member of the Alliance for Family Heidelberg. This corporate network is to exchange information and to ensure the various services in the field "work and family" and is a major hub. • MPIA is also on the distribution list of the Rhine-Neckar region and cooperates with the nationwide active corporate network "Erfolgsfaktor Familie".

The cross-linking of the MPIA with other scientific institutions, public bodies and business enterprises guaranteed the improvement and extension of the offers, the efficiency of each network partner and thus combines the energies in the implementation of important measures in Heidelberg as an attractive location for science.

Working Council

The members of the working council met on 50 meetings in the MPIA and with the other workings councils of the Heidelberg MPIs on March 3rd at the MPI for Comparative Public Law and International Law, and on October 17th at the MPIA.

Awards

The Ernst Patzer Prize winners of this year are:

The postdoc Elisabetta Caffau, ZAH, for her publication "An extremely primitive star in the Galactic halo", the IMPRS doctoral student Alexander Karim for his publication "The star formation history of mass-selected galaxies in the COSMOS field" and an den postdoc Andreas Schruba for his publication "A molecular star formation law in the atomic-gas-dominated regime in nearby galaxies".

Dimitrios A. Gouliermis received a fellowship "Comprehensive Characterization with HST of Stellar Populations in Star-Forming Regions of the Large Magellanic Cloud" (DLR Program 50 OR 908) and "The Stellar Clusters Population of the Andromeda Galaxy from the Panchromatic HST Survey" (DFG Program GO 1659/3-1).

Jouni Kainulainen, Hua-Bai Li, Sarah Ragan, Amy Stutz und Svitlana Zhukovska received a research grant from the DFG Priority Program "Physics of the Interstellar Medium".

Maren Mohler was awarded with the first prize of the Wilhelm and Else Heraeus Seminar for her poster "Extrasolar Planets – Towards comparative planetology beyond the Solar System" in Bad Honnef.

Karin Sandstrom received a Marie Curie International Incoming Fellowship.

Dmitry A. Semenov received a research grant "The first 10 million years of the Solar System – a Planetary Materials Approach" from the DFG (SPP 1385).

Cooperation with Industrial Companies

Adolf Pfeiffer GmbH, Mannheim
Aerotech GmbH, Nürnberg
Agilent Technologies Italia S., Leini
Air Liquide GmbH, Pfungstadt
Alcatel, Wertheim
Alternate Computer Versand, Linden
American Astronomical Society, Washington D.C.
Aqua Technik Gudat, Neulußheim
Arlt Computer GmbH & Co.KG, Heidelberg
asknet AG, Karlsruhe
Aufzug-Service M. Gramlich GmbH, Ketsch
AVIS, Oberursel
B+S Express Transport GmbH, Weinheim
Baader Planetarium GmbH, Mammendorf
Baier Digitaldruck, Heidelberg
Bechtle ÖA Direkt, Neckarsulm
Bürklin OHG, Oberhaching
Büro-Mix GmbH, Mannheim
CADFEM GmbH, Grafing
Carl Zeiss Optronics GmbH, Oberkochen
Computacenter AG & Co oHG, Stuttgart
COMTRONIC GmbH, Wilhelmsfeld
Conrad Electronic SE, Hirschau
Contag GmbH, Berlin
Cryophysics GmbH, Darmstadt
Dekra Akademie GmbH, Mannheim
DELL-Computer GmbH, Frankfurt
DELTA-V GmbH, Wuppertal
Deti GmbH, Meckesheim
DHL Express Germany GmbH, Köln
Digi-Key c/o US Bank Minneapol, Enschede
DPS Vakuum, Großrinderfeld
Drucker Druck, Bietigheim
DVS Dekont Vakuum Service GmbH, Erfurt
E. Strauss GmbH & Co., Biebergemünd
EDICO-Equipment GmbH, Nürnberg
Edmund Optics GmbH, Karlsruhe
Elektro-Steidl, Weinheim
ELMA Electronic GmbH, Pforzheim
ERNI Electronics GmbH, Adelberg
esd electronic system design g, Hannover
ESO - European Southern, Garching
EUROstor GmbH, Filderstadt
Faber Industrietechnik GmbH, Mannheim
Farnell GmbH, Oberhaching
Federal Express Europe Inc., Kelsterbach
Fels Fritz GmbH Fachspedition, Heidelberg
Fischer Elektronik GmbH & Co., Lüdenscheid
FlowCAD EDA-Software Vertrieb, Feldkirchen
Friedrich Wolf GmbH, Heidelberg
Fritz Zugck, Leimen
Funk Gruppe GmbH, Munich
Gabler Werbeagentur GmbH, Munich
Garlock GmbH, Neuss
Geier Metall-u.Stahlhandel GmbH, Mannheim
Gleich Service-Center Nord GmbH, Kaltenkirchen
Graeff Container-u.Hallenbau GmbH, Mannheim
Gummispezialhaus Körner, Eppelheim
Guttroff Friedrich GmbH, Wertheim
Häfele GmbH, Schriesheim
Hagemeyer Germany GmbH &Co, Heidelberg
Hahn u. Kolb GmbH, Stuttgart
Halle Bernhard Nachfl. GmbH, Berlin
Hauck GmbH, Heidelberg
Haufe Service Center GmbH, Freiburg i. Br.
Haus der Technik e.V., Essen
HELBIG Medizintechnik, Neuenstadt
Heuser Friedrich GmbH, Heidelberg
Hewlett Packard GMBH, Böblingen
Hewlett-Packard Direkt GmbH, Böblingen
HM Industrieservice GmbH, Kronau
Hoffmann, Göppingen
Hofmann Menü GmbH, Boxberg/ Schweigern
Hohmann Elektronik GmbH, Germering
HSD Consult GmbH, Munich
Hummer + Rieß GmbH, Nürnberg
HWP Architekturbüro, Heidelberg
infopaq Germany GmbH, Kornwestheim
Ingenieurbüro Schlossmacher, Unterschleissheim
INNEO Solutions GmbH, Ellwangen
IOP Publishing Ltd., Bristol
ITT Visual Informations GmbH, Gilching
Jacobi Eloxal GmbH, Altlussheim
JUMO GmbH & Co. KG, Fulda
Jungheinrich Vertrieb Germany, Hamburg
KA-WE GmbH, Schwetzingen
Kai Ortlieb Buchbinderei, Eppelheim
KAISER + KRAFT, Stuttgart
Kaufmann, Horst W., Crailsheim-Wittau
Keithley Instruments GmbH, Germering
Kniel GmbH, Karlsruhe
Konica Minolta Businesss, Mannheim
Körber TH. GmbH, Sensbachtal/Odw.
Kroll Ontrack GmbH, Böblingen
L.+H. Hochstein GmbH + Co., Heidelberg
Lapp Kabel GmbH, Stuttgart
Laser Components, Olching
Layertec GmbH, Mellingen
LD Didactic AG & Co.KG, Hürth
Lehmanns Fachbuchhandlung GmbH, Heidelberg
LEIPERT Maschinenbau GmbH, Kraichtal-Landshausen
Linde AG, Mainz-Kostheim
Lufthansa AirPlus GmbH, Neu Isenburg 1
Maas International GmbH, Bruchsal
Mayer GmbH Omnibusbetrieb, Neckargemünd-Dilsberg
Meilhaus Electronic GmbH, Puchheim
Melitta Systemservice GmbH & Co., Minden-Dützen
Melles Griot, Bensheim
Microstaxx GmbH, Munich
MTS Systemtechnik GmbH, Mertingen
Müller Otto GmbH, Bammental
Mura, Metallbau, Viernheim
Murrplastik-System-Technik, Oppenweiler
National Instruments GmbH, Munich
NET GmbH - DENNER HOTEL, Heidelberg
Neumann Rupert Druckerei, Heidelberg
Newport Spectra-Physics GmbH, Darmstadt
Nibler W. GmbH, Walldorf
Nies Elektronic GmbH, Frankfurt

Ocean Optics Germany GmbH, Ostfildern
Oerlikon, Köln
Omnilab GmbH, Berlin
Optima Research Ltd., Stansted
OWIS GmbH, Staufen
PFEIFFER VACUUM GmbH, Asslar
Pfister BÜRO, Leimen/St.Ilgen
Philipp Lahres GmbH, Weinheim
Physik Instrumente (PI), Karlsruhe
Phytec Messtechnik, Mainz
Polytec GmbH, Waldbronn
Pro-Com Datensysteme GmbH, Eislingen
REEG GmbH, Wiesloch
Reha-Klinik, Heidelberg
Reichelt Elektronik, Sande
Rexroth B., Lohr am Main
Rhein-Neckar-Zeitung, Heidelberg
Rheintourist Reisebüro oHG, Heidelberg
Rittal GmbH + Co.KG, Herborn
RS Components GmbH, Mörfelden-Walldorf
SAMTEC Germany, Germering
Sanitär-Raess GmbH, Heidelberg
Schäfer-Shop GmbH, Betzdorf
Schroff GmbH, Straubenhardt
Schulz H.u.G. Ingenieure, Heidelberg
SCHUPA Schumacher GmbH, Walldorf
servo Halbeck GmbH & Co.KG, Offenhausen
Siemens AG, Mannheim
Sky Blue Microsystems GmbH, Munich
SMS System-Managment, Aachen
SPHINX GmbH, Laudenbach
Stadtwerke Heidelberg AG, Heidelberg
Stäubli Tec Systems GmbH, Bayreuth
Swets Information Services, Frankfurt a.M.
synoTECH, Hückelhoven
Tautz Druckluft+Sandstrahltechnik, Mannheim
Technik Direkt, Würzburg
The MathWorks GmbH, Ismaning
Theile Büro-Systeme, Speyer
Thorlabs GmbH, Dachau
ThyssenKrupp Plastics GmbH, Mannheim
TLS Personenförderung GmbH, Heidelberg
Topcart International GmbH, Erzhausen
transtec AG, Tübingen
Trinos Vakuum-Systeme GmbH, Göttingen
TÜV Life Service GmbH, Munich
TÜV Süd Industrie Service GmbH, Mannheim
TWM Ottenstein GmbH, Mannheim
Tydex J.S.Co, St. Petersburg
United Parcel Service, Neuss
VA-TEC GmbH & Co.KG, Wertheim
VISION Engineering LTD, Emmering
Walter Bautz GmbH, Griesheim
Witzenmann GmbH, Pforzheim
Wolters Kluwer Germany, Neuwied

Conferences, Scientific, and Popular Talks

Conferences Organized

Conferences Organized at the institute:

Conference “Astronomy meets Business – 1st MPIA Job Information Day”, MPIA, 27. Jan. (K. Jäger, L. Burtscher, R. Andrae u.a.)

CARMENES Interface meeting, 10. Feb. (R. Lenzen)

Awarding of the pupils pizes of the “Agenda-Büro” of the city of Heidelberg at the MPIA/HdA, together with the LSW on 19. Apr. (C. Scorza, M. Pössel, K. Jäger, H. Mandel (LSW), Th. Henning, M. Voss, A. Quirrenbach (LSW) and others)

Book Presentation “Im Himmel über Heidelberg, 40 Jahre Max-Planck-Institut für Astronomie 1969 – 2009”, written by D. Lemke, 23. May (K. Jäger, M. Voss, D. Lemke, A. M. Quetz, M. Dueck, u.a.);

MPIA Internal Symposium, 25. May (G. van de Ven, H. Klahr, K. Jäger, and others)

Coordination Meeting with LBT representatives, 6. – 7. June (M. Kürster)

LINC-NIRVANA AIV Review, 8. – 9. June (M. Kürster, R. Hofferbert)

GRAVITY Progress Meeting, 4. – 5. July (R. Lenzen)

Pan-STARRS 1 Science Consortium – Key Project 5 summer meeting, 4. – 5. July (N. Martin, H.-W. Rix)

GRAVITY Consortium Meeting, MPIA, 4. – 6. July (S. Hippler, W. Brandner, S. Kendrew)

LN Science Team Meeting, 20 Oct. (E. Schinnerer)

LINC-NIRVANA Consortium Meeting, 20. – 21. Oct. (M. Kürster)

Commemorative Colloquium for Jakob Staude, MPIA/HdA, 15. Nov. (K. Jäger, M. Pössel, A. M. Quetz, U. Reichert, u.a.)

Visit to Germany – Japan Round Table am MPIA/HdA, 1. Dec. (Th. Henning, M. Pössel, K. Jäger u.a.);

Inauguration of the “Haus der Astronomie”, 16. Dec. (M. Pössel, M. Voss, K. Jäger, and others)

Other Conferences Organized:

Ringberg Conference on “Transport Processes and Accretion in YSO”, Ringberg Castle, 7. – 11. Feb. (R. van Boekel, A. Sicilia, M. Fang, Th. Henning)

Scientic Project Management, Max-Planck-Haus, Heidelberg, 14. Feb. (M. Kürster, M. Perryman)

LINC-NIRVANA Consortium Meeting, Padua, 24.–25. March, (M. Kürster)

GAIA DPAC CU8 plenary meeting, Liege, Belgium, 26.–27. May (C. A. L. Bailer-Jones)

Ringberg Workshop on “Geophysical and Astrophysical Fluid flow: Baroclinic Instability and Protoplanetary Accretion Disks”, Ringberg Castle, 14. – 18. June (Hubert Klahr, Helen Morrison, Natalie Raettig, Karsten Dittrich)

PAWS Team Meeting, Schloss Neuburg, 24. – 26. June (A. Hughes, S. Meidt, E. Schinnerer)

IMPRS Summer School “Characterizing exoplanets – from formation to atmospheres”, Max-Planck-Haus, Heidelberg, 1. – 5. Aug. (Chr. Fendt, K. Dullemond, L. Kaltenegger)

Annual Meeting of the Astronomische Gesellschaft “Surveys and Simulations – the real and the virtual Universe”, Sep. 19-34, Heidelberg (SOC-members: Th. Henning, H.-W. Rix, LOC-Member: K. Jäger)

Meeting “Public Outreach in der Astronomie” at the Annual Meeting of the Astronomische Gesellschaft in Heidelberg (K. Jäger, M. Pössel)

Splinter-Session “Formation, atmospheres and evolution of brown dwarfs” at the Annual Meeting of the AG in Heidelberg, 20. – 21. Sept. (V. Joergens, B. Biller, W. Brandner)

SEEDS 2nd General Workshop, Results, Techniques and New Developments, IWH, Heidelberg, 10. – 12. Oct. (B. Biller, M. Bonnefoy, M. Feld, Th. Henning)

Galaxy and Cosmology Department Retreat, Schloss Engers, Neuwied, 17. – 19. Oct. (B. Conn, E. da Cunha, H.-W. Rix, T.-H. Witte-Nguy)

Tagung “PSF workshop 2011”, Boppard am Rhein, 17. – 19. Oct. (R. van Boekel S. Zhukovska, Th. Henning)

MPIA-External Retreat, Obrigheim, 17. – 18. Nov. (K. Jäger, Th. Henning, H.-W. Rix, T.-H. Witte-Nguy)

Conferences and Meetings Attended, Scientific Talks and Poster Contributions

Angela Adamo: “PSF retreat”, Boppard, Oct. (Lecture); Head of the PSF splinter session “Clustered star formation”

Coryn A. L. Bailer-Jones: EPSC-DPS Joint meeting, Nantes, Oct. (Poster); “Surveys & Simulation – The Real and the Virtual Universe”, Annual Meeting of the AG, Heidelberg, 19. – 23. Sep. (Poster)

Zoltan Balog: PACS ICC meeting in Garching, 8. – 10. Feb.; OT1. DP Workshop als Tutor, ESAC in Madrid, Spain, 14. – 16. March, HCSS documentation Editorial Board meeting, London, UK, 21. – 26. Aug.; PACS Photometer Pipeline meeting, Heidelberg, 6. Oct.; PACS ICC meeting in Frascati, Italy, 17. – 18. Nov.

Myriam Benisty: Transport Processes and Accretion in YSOs, Ringberg Castle, 7. – 11. Feb. (Lecture); Ten years of the VLTI, ESO Garching, 24. – 27. Oct. (Lecture)

Carolina Bergfors: Exoplanets: Past, Present and Future, Lund, Schweden, 13. May; “From interacting binaries to exoplanet. – Essential modeling tools”, IAU Symposium 282, Tatranská Lomnica, Slowakei, 18. – 22. July (Poster); “Surveys & Simulation – The Real and the Virtual Universe”, Annual Meeting of the AG, Heidelberg, 19. – 23. Sep. (Poster); Formation and Evolution of Very Low Mass Stars and Brown Dwarfs, Garching, 11. – 14. Oct. (Poster)

Yan Betremieux: “Surveys & Simulation – The Real and the Virtual Universe”, Annual Meeting of the AG, Heidelberg, 19. – 23. Sep.; PSF retreat, MPIA, Oct.

Henrik Beuther: JENAM, St. Petersburg, Russia, 4. – 8. July (Lecture); SOFIA Community days, Stuttgart, Feb./ March, IRAM large program consortium meeting, Paris, France, June (Lecture)

Arjan Bik: Star Formation Across Space and Time: Frontier Science with the LBT and Other Large Telescopes”, Tucson, Arizona, USA, 31. Mar. – 2. Apr. (Lecture); “Stellar Clusters & Associations: A RIA Workshop on GAIA”, in Granada, Spain, 23. – 27. May (Lecture)

Tilman Birnstiel: “Planet Formation and Evolution”, Göttingen, 14. – 16. Feb. (Lecture); ESO Headquaters, Garching, Jan. (Lecture); MPIK, Heidelberg, Feb. (Lecture); ILTS, Sapporo, Japan, Feb. (Lecture); University of Nagoya, Japan, Feb. (Lecture); University of Kyoto, Japan, Feb. (Lecture); USM, Munich, May (Lecture)

Paul Boley: “Resolving the future of astronomy with long-baseline interferometry”, Socorro, NM, USA, 28. – 31. March (Poster); “Physics of Space: 40th Scientific Conference for Students” Kourovka, Russia, 31. Jan. – 4. Feb. (Lecture)

Mickaël Bonnefoy: Conference Exploring Strange New Worlds, Flagstaff, USA, 1. – 6. May (Poster)

Mauricio Cisternas: “2011. COSMOS Team meeting”, Zürich, Schweiz, 15. June (Lecture); “Galaxy Mergers in an Evolving Universe” Hualien, Taiwan, 23. Oct. (Lecture)

Michelle Collins: The Third SUBARU International Conference on Galactic Archaeology, Shuzenji, Japan, 1. – 4. Nov. (Poster)

Blair Conn: Assembling the puzzle of the Milky Way, Le Grand-Bornand France, 17. – 22. Apr. (Poster); “Surveys & Simulation – The Real and the Virtual Universe”, Annual Meeting of the AG, Heidelberg, 19. – 23. Sep. (Lecture); The 3rd SUBARU Annual Conference, Shuzenji, Japan, 1. – 4. Nov. (Poster)

Albert Conrad: Adaptive Optics Real-time Control System Workshop, Durham, UK, 13. – 14. Apr. (Lecture); Adaptive Optics for Extremely Large Telescopes II (AO4ELT2), Victoria, BC, Canada, 25. – 30. Sep. (Poster); European Planetary Science Congress and the Division for Planetary Sciences of the American Astronomical Society (EPSC-DPS) Joint meeting, Nantes, France, 3. – 7. Oct. (Poster)

Neil Crighton: “The Cosmic Odyssey of Baryons: accreting, outflowing and hiding” Conference, Marseille, France, 20. – 24. June (Poster)

Elisabete da Cunha: 3D-HST meeting, Leiden, The Netherlands, 4. March (Lecture); 3D-HST meeting, Yale, US, 9. – 12. May (Lecture); “Multiwavelength Views of the ISM in High-Redshift Galaxies”, ESO Conference, Santiago, Chile, 27. – 30. June (Lecture); “The Spectral Energy Distribution of Galaxies”, IAU Symposium, Preston, UK, 5. – 9. Sep. (Lecture); 3D-HST meeting, Leiden, The Netherlands, 10. – 14. Oct. (Lecture); MPIA Galaxies & Cosmology department retreat, Schloss Engers, 17. – 19. Oct. (Lecture); “Watching Galaxies Grow Up”, Ringberg Workshop, Ringberg Castle, 5. – 9. Dec.

Roberto Decarli: Bridging electromagnetic astrophysics and cosmology with gravitational waves, Milano, Italy, 28. – 30. March (Lecture); Narrow line Seyfert 1. Galaxies and their place in the Universe, Milano, Italy, 4. – 6. Apr. (Lecture); Pan-STARRS Consortium meeting, Cambridge, USA, 18. – 21. May; “Single and dual black holes in galaxies”, Ann Arbour, USA, 22. – 25. Aug. (Lecture)

Karsten Dittrich: HGSFP Winter School, Obergurgl, Österreich, 16. – 20. Jan. (Poster); Plant Formation and Evolution, Göttingen, 14. – 16. Feb. (Poster); Saas Fee Advanced Course, Villars-sur-Ollon, Schweiz, 3. – 9. Apr.; Baroclinic Discs, Ringberg Castle, 14. – 18. June (Lecture); “Surveys & Simulation – The Real and the Virtual Universe”, Annual Meeting of the AG, Heidelberg, 19. – 23. Sep.; SPP Treffen, Mainz, 17. – 19. Oct. (Lecture)

Markus Feldt: “Surveys & Simulation – The Real and the Virtual Universe”, Annual Meeting of the AG, Heidelberg, 19. – 23. Sep. (Lecture)

Wolfgang Gässler: ARGOS consortium meeting, OAA, Florence, Italy, 22. – 23. March (Lecture); ARGOS consortium meeting, LBTO, Tucson, USA, 11. – 12. Aug. (Lecture); ARGOS meeting on Tip/Tilt sensor, MPIA, Heidelberg, 12. – 13. Sep.; ARGOS software meeting, MPE, Garching, 14. – 16. Nov; ARGOS software meeting, OAA, Florence, Italy, 12. – 14. Dec.

Mario Gennaro: Stellar Clusters & Association – A RIA workshop on GAIA, Granada, Spain, May (Lecture)

Bertrand Goldman: “Surveys & Simulation – The Real and the Virtual Universe”, Annual Meeting of the AG, Heidelberg, 19. – 23. Sep. (Poster, Lecture)

Brent Groves: “DF-SPP: Physics of the Interstellar Medium”, Freising, 2. – 3. March (Poster); “HERSCHEL and the Characteristics of Dust in Galaxies”, Lorentz Centre, Leiden, The Netherlands, 28. Feb. – 4. March (Lecture); “KINGFISH Team meeting, IAP, Paris, France, 3. – 5. July (Lecture); “IAU Symp. 284: The Spectral Energy Distribution of Galaxies”, UCLan, Preston, UK, 5. – 9. Sep. (Lecture)

Siddharth Hegde: “Extrasolar Planets: Towards Comparative Planetology beyond the Solar System”, 483. Wilhelm and Else Heraeus Seminar, Bad Honnef, 5. – 8. June; Characterizing Exoplanet – From Formation to Atmospheres”, 6th Heidelberg Summer School “, Heidelberg, 1. – 5. Aug.; “Characterizing Extrasolar Planet – from Giant to Rocky Planets”, Annual Meeting of the AG, Heidelberg, 19. – 24. Sep. (Poster); “From the Early Universe to the Evolution of Life”, German-Japan Round Table Conference, Heidelberg, 1. – 3. Dec. (Poster); “Sao Paulo Advanced School of Astrobiology (SPASA)”, Summer School, Sao Paulo, Brazil, 11. – 20. Dec. (Poster)

Thomas Henning: "Surveys & Simulation – The Real and the Virtual Universe", Annual Meeting of the AG, Heidelberg, 19. – 23. Sep. (Lecture); PS1. Consortium meeting, Harvard, USA, 16. – 20. May; HOPS Consortium meeting, Rochester, USA, 18. May; DIGIT Consortium meeting, Pasadena, USA, 11. – 15. July

Stefan Hippler: GRAVITY Consortium meeting, ESO Garching, 31. Mar. – 1. Apr.; METIS Team meeting: MPE Garching, 27. – 29. June; Ten years of VLTI: From First FRINGEs to Core Science, Conference, ESO Garching, 24. – 27. Oct. (Poster)

Jacqueline A. Hodge: German ALMA Early Science Community Day, Bonn, 16. – 17. Feb.; Multiwavelength Views of the ISM in High-Redshift Galaxies, Santiago, Chile, 27. – 30. June (Lecture); Galaxy Mergers in an Evolving Universe, Hualien, Taiwan, 23. – 28. Oct. (Lecture)

Rory Holmes: SPIE Optics + Photonics, San Diego, USA, 12. – 14. Aug. (Poster)

Annie Hughes: "MW2011. The Milky Way In The HERSCHEL Era: Towards A Galaxy-Scale View Of The Star Formation Life-Cycle", Rome, Italy, 19. – 23. Sep. (Lecture and Poster); "Formation and Development of Molecular Cloud – prospects for high resolution spectroscopy with CCAT", Cologne, 5. – 7. Oct. (Poster)

Cornelia Jäger: "Formation of GEMS from interstellar silicate dust." 2nd Annual meeting of the SPP 1385, Mainz, 17. – 19. Oct. (Lecture); "UV-VIS spectroscopy of astrophysically relevant PAHs", 23rd International Symposium on Polycyclic Aromatic Compounds (ISPAC23), Münster, September 4. – 8. Sep. (Poster)

Klaus Jäger: Meeting of the Rat Deutscher Sternwarten (RDS), Max-Planck-Institut für Extraterrestrische Physik, Garching, 23. March, meeting of the LBT-associated company (LBTB), Max-Planck-Institut für Radioastronomie, Bonn, 12. Apr.; Naturejobs Career Expo, European Molecular Laboratory (EMBL), (Lecture), Advanced Training Centre, Heidelberg, 9. May; Meeting of the scientific council of the "International Summer Science School Heidelberg", Palais Graimberg, Heidelberg, 26. May; Meeting of the Rat Deutscher Sternwarten (RDS), Heidelberg University, 19. Sep.; "Surveys & Simulation – The Real and the Virtual Universe", Annual Meeting of the AG, Heidelberg, 19. – 24. Sep.; Meeting of the scientific council of the "International Summer Science School Heidelberg", Palais Graimberg, Heidelberg, 13. Oct.; Visit of the German-Japan Round Table at the MPIA/HdA, Heidelberg, 1. Dec. (Lecture).

Katharine G. Johnston: German ALMA Early Science Community Day, Bonn, 16. – 17. Feb.; Formation and Development of Molecular Cloud – prospects for high resolution spectroscopy with CCAT, Cologne University, 5. – 7. Oct.

Jouni Kainulainen: The Milky Way in the HERSCHEL Era, Rome, Italy, 19. – 23. Sep. (Lecture and Poster)

Vesselina Kalinova: 1st project meeting of CALIFA survey, Almeria, Spain, Apr. (Lecture); Conference Galaxy evolution, Durham University, UK, July (Poster); Galaxy coffee, MPIA Heidelberg, Aug. (Lecture); Winter School of Astrophysics "Secular Evolution of Galaxies", Puerto de La Cruz, Tenerife, Spain, 14. – 25. Nov. (Poster); 2nd project meeting of CALIFA survey, La Laguna, Tenerife, Spain, 29. Nov. – 2. Dec. (Lecture)

Lisa Kaltenegger: Lecture Board of Trustees, 11. Oct.;

EChO meeting, Paris, France, Apr.; METIS meeting, MPE, Garching, June; TESS meeting, MIT, Boston, USA, Oct.; GMT meeting, CfA, Boston, USA, Oct.

Alexander Karim: annual COSMOS collaboration meeting, ETH Zürich, 17. June (Lecture); Public outreach splinter of the annual meeting of the AG, Heidelberg, 22. Sep. (Lecture); High redshift star formation splinter of the annual meeting of the AG, Heidelberg, 21. Sep. (Lecture)

Sarah Kendrew: GRAVITY science meeting, Paris, France, 3. – 4. Jan; SciFoo conference, Googleplex, Mountain View, California, USA, 12. – 14. Aug. (invitation-only); The multi-wavelength view of the Galactic Centre workshop, Heidelberg, 17. – 20. Oct.

Ulrich Klaas: PACS ICC meeting #37, Garching, 8. – 10. Feb.

Hubert Klahr: Transport Processes and Accretion in YSO's, Ringberg Castle, 7. – 11. Feb. (Lecture)

Rainer Köhler: "Astronomy with Long-Baseline Interferometry", Socorro, New Mexico, USA, 28. – 31. March (Poster); "Surveys & Simulations – The Real and the Virtual Universe", Annual Meeting of the AG, Heidelberg, 19. – 23. Sep. (Poster); "Formation and Early Evolution of Very Low Mass Stars and Brown Dwarfs", ESO Garching, 11. – 14. Oct. (Poster)

Serge A. Krasnokutski: "Reactions of Si atoms and clusters in helium nanodroplets", 482nd Wilhelm and Else Heraeus Seminar: Helium Nanodroplet – Confinement for Cold Molecules and Cold Chemistry, Bad Honnef, 30. May – 1. June (Poster)

Oliver Krause: SOFIA Community day, University Stuttgart, Feb.; Conference Exploring Strange New Worlds, Flagstaff, USA, May (Poster); Binary Pathways to type Ia Supernova explosions – IAU Symposium 281: Padua, Italy, June (Poster);

The Third SUBARU International Conference on Galactic Archaeology, Shuzenji, Japan, Nov. (Lecture)

Natalia Kudryavtseva: Paris GRAVITY science team meeting, Paris, France, Feb. (Lecture); "Ten years of VLTI", Garching Conference, Garchin, Oct. (Poster)

Martin Kürster: Scientific Project Management, Max Planck House Heidelberg, 14. Feb. (with M. Perryman)

Ralf Launhardt: The Milky Way in the HERSCHEL Era, Rome, Italy, 19. – 23. Sep. (Poster)

Roger Lee: "Surveys & Simulation – The Real and the Virtual Universe", Annual Meeting of the AG, Heidelberg, 19. – 23. Sep.

Christian Leipski: New Horizons for High Redshift, Cambridge, UK, 25. – 29. July (Attendee); The Central Kiloparsec in Galactic Nuclei, Bad Honnef, 29. Aug. – 2. Sep. (Lecture)

Dietrich Lemke: "400 Jahre Sternwarten in Heidelberg und der Kurpfalz – Vom Universitätsgarten in der Plöck zum Max-Planck-Institut für Astronomie auf dem Königstuhl", Annual Meeting of the Astronomische Gesellschaft, Workshop Astronomie-Geschichte, Mannheim, 19. Sep. (Lecture)

Rainer Lenzen: METIS Calibration, Universität Leuven, Belgium, 21. Jan.; GRAVITY progress meeting, MPE Garching, 31. May – 1. Apr.; METIS progress meeting, MPE Garching, 28. – 29. June; Carmenes Preliminary Design Review, CSIC headquarters, Madrid, Spain, 18. – 21. July; CARMENES FDR Preparation meeting, TH Zürich, Schweiz, 4. – 7. Oct.; Conference on Polarimetry with the E-ELT, Universität Utrecht, The Netherlands, 29. – 30. Nov; CARMENES meeting, IAA Granada, Spain, 12. – 14. Dec.

Hendrik Linz: ATLASGAL Consortium meeting, MPIfR Bonn, 18. May; HERSCHEL/PACS ICC meeting, MPE Garching, 1. May – 1. June; "Resolving the Future of Astronomy with Long-Baseline Interferometry", Magdalena Ridge Observatory Interferometry Workshop New Mexico Tech, Fidel Center, Socorro, New Mexico, USA, 28. – 31. March (Poster); Conference MW2011: The Milky Way in the HERSCHEL Era "Angelicum" Congress Centre, Rome, Italy, 19. – 23. Sep. (Lecture); Retreat of the PSF Department of MPIA, Boppard, 17. – 19. Oct.; HERSCHEL/PACS ICC meeting, IFSI Rome, Italy, 17. – 18. Nov.

Nils Lippok: The Milky Way in the HERSCHEL Era, Rome, Italy, 19. – 23. Sep. (Poster); Formation and Early Evolution of Very Low Mass Stars and Brown Dwarfs, ESO Garching, 11. – 14. Nov. (Poster)

Mariya Lyubenova: CALIFA Busy Week 2, IAC, La Laguna, Tenerife, Spain, 29. Nov. – 2. Dec. (Lecture)

Andrea V. Macciò: Galaxy Formation, Durham, UK, 18. – 22. July (Poster)

Luigi Mancini: XV International Conference on Gravitational Microlensing, University of Salerno, Salerno, Italy, 20. – 22. Jan. (Lecture); "Surveys & Simulation – The Real and the Virtual Universe", Annual Meeting of the AG, Heidelberg, 19. – 23. Sep.; Exoplanetary Science with HARPS-N, Padova, Italy, 28. – 29. Nov. (Lecture)

Nicholas Martin: PAndAS Collaboration meeting, Toronto, Canada, 28. – 30. March (Lecture); "Assembling the Puzzle of the Milky Way", Le Grand Bornand, France, 18. – 22. Apr. (Lecture); Pan-STARRS 1. Science Consortium meeting, Boston, USA, 18. – 20. May (Lecture); American Astronomical Society meeting, Boston, USA, 23. – 27. May 23.-27. (Lecture); Pan-STARRS 1. Science Consortium – Key Project 5. Summer meeting, Heidelberg, 4. – 5. July (Lecture); "Galaxy Formation", Durham, UK, 18. – 22. July (Lecture); The Third SUBARU International Conference, Shuzenji, Japan, 1. – 4. Nov.

Klaus Meisenheimer: "Surveys & Simulation – The Real and the Virtual Universe", Annual Meeting of the AG, Heidelberg, 19. – 23. Sep.

Yamila Miguel: "Wilhelm and Else Heraeus Seminar Extrasolar Planets: Towards Comparative Planetology beyond the Solar System", Bad Honnef, 5. – 8. June (Poster); "WG3. Nitrogen in planetary systems: The Early Evolution of the Atmospheres of Terrestrial Planets", Institute of Space Sciences (CSIC-IEEC), Barcelona, Spain, 21. – 23. Sep. (Lecture); "German-Japan Round Table: From the Early Universe to the Evolution of Life", Heidelberg University, 1. – 3. Dec. (Poster); "SPASA: SaoPaulo Advanced School of Astrobiology", Universidade de Sao Paulo. Instituto de Astronomia, Geofisica e Ciencias Atmosfericas:, Sao Paulo, Brasilien, 11. – 20. Dec. (Poster)

Maren Mohler: Planet formation and evolution, Göttingen, 14. – 16. Feb. (Poster); 14th ESPRI science team meeting, Heidelberg, 26. – 27. May; "Extrasolar Planet – Towards comparative planetology beyond the Solar System", Wilhelm and Else Heraeus Seminar, Bad Honnef, 6. – 8. June (Poster); "Characterizing extrasolar planet atmospheres", Summerschool, Heidelberg, 1. – 5. Aug.; "Surveys & Simulation – The Real and the Virtual Universe", Annual Meeting of the AG, Heidelberg, 19. – 23. Sep.; PSF retreat, 17. – 19. Oct. (Boppard, Lecture); ESPRI science team meeting, Garching, 7. Nov.

Christoph Mordasini: EChO workshop, Paris, France, 24. March (Lecture); Extreme Solar Systems II conference, Jackson Hole, USA, 16. Sep. (Lecture); German-Japan Round Table meeting, Heidelberg, 5. Dec. (Lecture)

Helen Morrison: "Planet Formation and Evolution" Göttingen, 14. – 16. Feb. (Poster)

André Müller: MPIA PSF group retreat, Boppard am Rhein, 17. – 19. Oct. (Lecture); MPIA PSF-Seminar, 27. July (Lecture)

Reinhard Mundt: 217th AAS Meetin Seattle, WA, 9. – 13. Jan. (Poster); "CARMENES technical meeting on NIR channel interfaces", MPIA Heidelberg, 9. – 10. Feb.; CARMENES Preliminary Design Review, Madrid, Spain, 18. – 21. July; 1st CARMENES technical meeting for FDR preparation, LSW, Heidelberg, 4. – 7. Oct.; First CARMENES Science meeting, Göttingen, 5. – 7. Oct.

Markus Nielbock: HERSCHEL PACS ICC meeting, MPE, Garching, 8. – 10. Feb. (Lecture); MPG Science Management Seminar, NH Hotel, Hamburg, 11. March, HERSCHEL Calibration Steering Group meeting, ESTEC, Noordwijk, The Netherlands, 12. Apr. (Lecture); HERSCHEL: In Orbit Performance Review, ESOC, Darmstadt, 24. May; HERSCHEL PACS ICC meeting, MPE, Garching, 31. May – 1. June (Lecture); HERSCHEL Calibration Steering Group meeting, MPE, Garching, 9. Sep. (Lecture); "Surveys & Simulation – The Real and the Virtual Universe", Annual Meeting of the AG, Heidelberg, 19. – 23. Sep.; HERSCHEL PACS Photometer Calibration Colocation, MPIA Heidelberg, 6. Oct.; MPIA PSF Group Retreat, Boppard, 17. – 19. Oct.; HERSCHEL PACS ICC meeting, IFSI, Rome/Frascati, Italy, 17. – 18. Nov. (Lecture); HERSCHEL Pointing Working Group meeting, ESOC, Darmstadt, 29. – 30. Nov.

Sladjana Nikolic: Cosmic rays and their interstellar medium environment, Montpellier, France, 26. Jun. – 1. July (Poster); 16th National conference of astronomers of Serbia, Belgrade, Serbia, 10. – 12. Oct. (Lecture); Summer school: High energy astrophysics, Dublin, Ireland, 3. – 15. July

Johan Olofsson: “Planet Formation and Evolution”, Göttingen, Feb. (Lecture)

Alexey Pavlov: SPHERE Data Reduction and Handling meeting, IWH (Internationales Wissenschaftsforum Heidelberg), Heidelberg, 19. – 21. Jan, (Organisator, Lecture); SPHERE Science-DRH meeting, IPAG, Grenoble, France, 12. – 14. Oct. (Lecture)

Diethard Peter: AO4ELT2, Victoria, Canada, 25. – 30. Sep. (Poster)

Oliver Porth: Understanding Relativistic Jets, Krakow, Poland, 23. – 26. May (Poster); “The Central Kiloparsec in Galactic Nuclei (AHAR11)”, Bad Honnef, 29. Aug. – 2. Sep. (Lecture)

Axel M. Quetz: “Surveys & Simulation – The Real and the Virtual Universe”, Annual Meeting of the AG, Heidelberg, 19. – 23. Sep.

Natalie Raettig: Planet Formation and Evolution, Göttingen, 14. – 16. Feb. (Lecture); Ringberg Workshop on “Geophysical and Astrophysical Fluid Flow: Baraclinic Instability and Protoplanetary Accretion Disks”, Ringberg Castle, 14. – 18. June (Lecture)

Sarah Ragan: Building on New Worlds, New Horizons, Santa Fe, New Mexico, USA, 7. – 10. March (Lecture); ALMA community days, ESO Garching, 6. – 7. Apr.; MW2011: The Milky Way in the HERSCHEL Era, Rome, Italy, 19. – 23. Sep. (Poster); “Formation and Development of Molecular Cloud – prospects for high resolution spectroscopy with CCAT”, Cologne, 5. – 7. Oct. (Poster)

Hans-Walter Rix: EUCLID Consortium meeting, ESTEC Amsterdam, The Netherlands, 27. May; GREAT meeting, IAP Paris, France, 10. June; Galaxy Formation Conference, Durham, UK, 18. – 20. July; “Surveys & Simulation – The Real and the Virtual Universe”, Annual Meeting of the AG, Heidelberg, 19. – 23. Sep.; NIRSPEC Science meeting, Madrid, Spain, 4. – 5. Oct.; PHAT meeting, Seattle, USA, 9. – 12. Nov.

Boyke Rochau: Stellar Clusters & Associations: A RIA Workshop on GAIA, Granada, Spain, 23. – 27. May (Lecture)

Ralf-Rainer Rohloff: Annular meeting of the American Society for Precision Engineering, Denver, USA, 13. – 18. Nov.

Gaël Rouillé: “Spectroscopy of PAHs with carbon side chains”, IAU Symposium 280: The Molecular Universe, Toledo, Spain, 30. May – 3. June; “A search for PAHs in the ISM: High-resolution UV observations confronted with laboratory spectra”, IAU Symposium 280: The Molecular Universe, Toledo, Spain, 30. May – 3. June (Poster) (together with R. Gredel, Y. Carpentier, M. Steglich, F. Huisken, Th. Henning)

Karin Sandstrom: “From Dust to Galaxies” Paris, France, 27. Jun. – 2. July (Lecture); “HERSCHEL and the Characteristics of Dust in Galaxies”, Leiden, The Netherlands, 28. Feb. – 4. March (Lecture); 217th American Astronomical Society meeting, Seattle, USA, 9. – 13. Jan. (Lecture)

Silvia Scheithauer: JWST MIRI European Consortium meeting, Leiden, The Netherlands, 6. – 8. Sep.; “Surveys & Simulation – The Real and the Virtual Universe”, Annual Meeting of the AG, Heidelberg, 19. – 23. Sep.

Eva Schinnerer: 217th meeting of the American Astronomical Society, Seattle, USA, 9. – 13. Jan. (Poster); “Extending the Limits of Astrophysical Spectroscopy”, ALMA Workshop, Victoria, Canada, 15. – 18. Jan; COSMOS Team meeting, ETH/Zürich, Schweiz, 13. – 17. June (Lecture); KINGFISH Team meeting, IAP, Paris, France, 4. – 5. July (Lecture); LN Consortium meeting, MPIA, Heidelberg, 20. – 21. Oct. (Lecture)

Kasper Borello Schmidt: 3D-HST meeting, Leiden, The Netherlands, 3. – 7. March (Lecture); 3D-HST meeting, New Haven, USA, 9. – 12. May (Lecture); “How a Space Project Works”, ELIXIR School, Nordwijk, The Netherlands, 18. – 21. May; “Galaxy Formation”, Durham, UK, 18. – 22. July (Poster); ELIXIR annual meeting, Madrid, Spain, 5. – 6. Oct. (Lecture); 3D-HST meeting, Leiden, The Netherlands, 10. – 14. Oct. (Lecture)

Kirsten Schnülle: AHAR (Astronomy at high angular resolution) conference, Bad Honnef, 29. Aug. – 2. Sep. (Poster)

Andreas Schruba: 217th AAS meeting, Seattle, USA, 9. – 13. Jan. (Dissertationsvortrag); SPP Workshop of DFG Priority Programme 1177, Bad Honnef, 7. – 9. July (Lecture); ALMA Community Day, ESO, Garching, 6. – 7. Apr.

Tim Schulze-Hartung: ESPRI Science Team meeting, Heidelberg, 26. – 27. May; ESPRI Science Team meeting, Garching, 7. Nov.

Dmitry A. Semenov: German-Japanese meeting, Uni Heidelberg, 1. – 3. Dec. (Poster); “Isotopes in Astrochemistry”, Lorentz workshop, Leiden, The Netherlands, Dec. 5. – 9. Dec. (Chair)

Aurora Sicilia: “Ringberg Conference on Transport Processes and Accretion in YSO”, Ringberg Castle, Feb. (Lecture)

Robert Singh: “Surveys & Simulation – The Real and the Virtual Universe”, Annual Meeting of the AG, Heidelberg, 19. – 23. Sep.; CALIFA 2nd Busy Week, IAC at La Laguna, Tenerife, 29. Nov. – 2. Dec. (Lecture)

Kester Smith: “Astrostatistics and data mining in large astronomical surveys”, La Palma, Spain, 30. May – 3. June (Lecture)

Mathias Steglich: “Electronic spectroscopy of neutral and ionized PAHs in inert gas matrices?”, International Conference on Interstellar Dust, Molecules and Chemistry, Pune, India, 22. – 25. Nov. (Lecture)

Greg Stinson: "Surveys & Simulation – The Real and the Virtual Universe", Annual Meeting of the AG, Heidelberg, 19. – 23. Sep.; "Watching Galaxies Grow Up", Ringberg Castle, 4. – 9. Dec.

Amelia Stutz: AAS, Seattle, WA, 9. – 13. Jan. (Lecture); ISM-SPP, Freising, 2. – 3. May (Poster); HOPS meeting, Rochester, USA, 16. – 20. May (Lecture); The Milky Way in the HERSCHEL Era, Rome, Italy, 19. – 23. Sep. (Poster); PSF workshop, 17. – 19. Oct.

Paraskevi Tsalmantza: "8th GAIA CU8. meeting", Liege, Belgium, 4. – 5. May (Lecture); "Joint Workshop & Summer School on Astrostatistics and Data Mining of Large Astronomical Databases", La Palma, Canary islands, Spain, 30. May – 3. June (Lecture)

Ana Uribe: Advances in Computational Astrophysics, Cefalu, Italy, June (Poster)

Roy van Boekel: EChO community meeting, Meudon, France, 23. – 24. March (Lecture)

Glenn van de Ven: "1st CALIFA Busy Week", Almeria, Spain, 11. – 15. Apr. (Lecture); "Expanding the Universe", Tartu, Estland, 27. – 29. Apr.; "Surveys & Simulation – The Real and the Virtual Universe", Annual Meeting of the AG, Heidelberg, 19. – 23. Sep.; MPIA Galaxy & Cosmology Retreat, Neuwied, 17. – 19. Oct. (Lecture)

Tessel van der Laan: KINGFISH team meeting, Paris, France, 4. – 5. July, AHAR2011, Bad Honnef, 28. Aug. – 2. Sep. (Lecture); IMPRS retreat, Köllbachhaus Simmersfeld, 23. – 26. March (Lecture)

Arjen van der Wel: "Galaxy Formation", Durham, UK, 18. – 22. July (Lecture); "Watching Galaxies Grow Up", Ringberg Castle, 4. – 9. Dec. (Lecture)

Bram Venemans: VST ATLAS Science Kick-off meeting, Durham, UK 5. Dec. (Lecture)

Fabian Walter: ALMA Regional Center meeting, Bonn University, Bonn, Feb.; Pan-STARRS 1. Collaboration meeting, CfA Cambridge, USA May; ESO ALMA meeting, Santiago, Chile, June (Lecture)

Laura Watkins: "Assembling the Puzzle of the Milky Way", Le Grand-Bornand, France, 17. – 22. Apr. (Lecture); "Surveys & Simulation – The Real and the Virtual Universe", Annual Meeting of the AG, Heidelberg, 19. – 23. Sep.

Yujin Yang: "The Cosmic Odyssey of Baryons: accreting, outflowing and hiding", Conference, Marseille, France, 20. – 24. June (Lecture); Conference "Young and Bright: Understanding High Redshift Structures", Potsdam, 12. – 16. Sep. (Lecture)

Miaomiao Zhang: "Stellar Clusters and Associations-A RIA Workshop on GAIA", The Congress Centre of Granada, Spain, 23. – 27. May (Poster)

Xianyu Zhang: "Optimal Natural Guide Star Acquisition for the LINC-NIRVANA MCAO system", Victoria, Canada, 25. – 30. Sep.;

Svitlana Zhukovska: "From Dust to Galaxies", Paris, France, 27. Jun. – 1. July (Poster); PSF workshop, MPIA Heidelberg, 17. – 19. Oct. (Lecture)

Invited Talks, Colloquia

Coryn A. L. Bailer-Jones: "Unravelling the impact of astronomical phenomena on the Earth", Institute for Astrophysics, Universität Göttingen, Dec. (Colloquium)

Myriam Benisty: Institut de Planetologie et d'Astrophysique de Grenoble, Grenoble, France, Feb. (Colloquium); Sterrenkundig Instituut "Anton Pannekoek", Amsterdam, The Netherlands, Nov. (Colloquium)

Henrik Beuther: University Calgary, Canada, Oct. (Colloquium); Hertzberg Institute for Astronomy, Victoria, Canada, Oct. (Colloquium)

Arjan Bik: Seminar at the massive star group meeting, University of Amsterdam, Amsterdam, The Netherlands, 11. March

Tilman Birnstiel: "Baroclinic Disks", Ringberg Castle, 14. – 17. June (Lecture)

Paul Boley: "Radiative transfer and spectra of objects from the interstellar medium," Kourovka, Russia, 4. – 5. Feb. (Lecture)

Mickaël Bonnefoy: "The Beta Pictoris system: a disk, a planet, and much more", MPIA Heidelberg, 20. May (Colloquium); "NIR spectra of young low mass companions: from observations to theory", MPIA Heidelberg, 20. Dec. (Colloquium), "The Beta Pictoris system: a disk, a planet, and much more", IFA, Honolulu, Hawaii, 21. March (Colloquium)

Mauricio Cisternas: MPIA & LSW Hauskolloquium, MPIA Heidelberg, 18. Feb. (Colloquium)

Albert Conrad: The Astronomy Department of the University of California at Berkeley, 20. Aug. (Colloquium)

Elisabete da Cunha: "Star formation in galaxy clusters", Workshop, Nice, France, 6. – 8. June (Lecture)

Niall Deacon: "A solar neighbourhood proper motion survey with PS1+2MASS", ESO Seminar, Formation and Early Evolution of Very Low Mass Stars and Brown Dwarfs, Garching, 12. Oct. (Lecture)

Roberto Decarli: "Single and dual black holes in galaxies", Ann Arbour, USA, 22. – 25. Aug. (Lecture)

Kees Dullemond: Ringberg meeting on accretion, Ringberg Castle, 7. – 9. Feb. (Lecture); Meeting on planet formation, Goettingen, 14. – 16. Feb. (Lecture); Exoplanet Meeting, Bad Honnef, 5. – 8. June (Lecture); Joint Colloquium, Leiden Observatory, Leiden, The Netherlands, 27. Jan. (Colloquium); Colloquium, Lund Observatory, Lund, Sweden, 31. March (Colloquium); Colloquium, University of Kiel, 6. July (Colloquium)

Christian Fendt: "MHD simulations of jet formation – relativistic jets and radiative jets", Conference: "The central kiloparsec in galactic nuclei", Bad Honnef, 29. Aug. – 2. Sep. (Lecture)

Wolfgang Gässler: 112. Jahrestagung Deutsche Gesellschaft für Angewandte Optik, TU Ilmenau, 14. – 18. June (Lecture)

Dimitrios A. Gouliermis: Colloquium at the Stellar Population Journal Club, STScI, Baltimore MD, USA, 22. July (Colloquium)

Roland Gredel: KIS Freiburg, 8. Dec. (Colloquium)

Brent Groves: “From Dust to Galaxies”, IAP, Paris France, 27. June – 1. July

Thomas Henning: Transport Processes and Accretion in YSOs, Ringberg Castle, 7. – 11. Feb. (Lecture); HERSCHEL and the Characteristics of Dust in Galaxies, Workshop, Leiden, The Netherlands, 28. Feb. – 4. March (Lecture); Star Formation across Space and Time: Frontier Science with the LBT and other Large Facilities, Tucson, USA, 31. March – 2. Apr. (Lecture); Molecular Networks: Connecting the Universe, Amsterdam, The Netherlands, 18. – 20. Apr. (Lecture); Frontier Science Opportunities with the James Webb Space Telescope, Baltimore, USA, 6. – 8. June (Lecture); “From Dust to Galaxies”, IAP-SAP Colloquium, Paris, France, 24. June – 1. July (Lecture); “Star Formation across the Universe”, Summer School, Alpbach, Österreich, 19. – 23. Jul1 (Invited Talk and Discussions); European Conference on Laboratory Astrophysics, Paris, France, 26. – 30. Sep. (Lecture); International Conference on Interstellar Dust, Molecules, and Chemistry, Pune, India, 22. – 25. Nov. (Lecture); Formation of Massive Stars, University of Vienna, Austria, 27. June (Colloquium); From Protoplanetary Disks to Extrasolar Planets, Littrow Lecture, Austrian Academy of Sciences, Wien, Austria, 12. Oct. 2012. (Colloquium); Protoplanetary Disks: From Dust to Gas, Berkeley, USA, 27. Oct. (Colloquium)

Friedrich Huisken: “Optical properties of silicon-based nanomaterials: Ensemble and single particle spectroscopy of silicon nanocrystals and silicon oxide nanoparticles”, Korean Institute of Energy Research, University of Daejeon, South Korea, 28. March (Seminar); “Photoluminescence studies on size-selected silicon nanocrystals”, School of Materials Science and Engineering, University of Ulsan, South Korea, 29. March (Seminar); “Laboratory Experiments for the Interpretation of Astrophysical Phenomena”, Seminar des Sonderforschungsbereichs 956, I. Physikalisches Institut der Universität zu Köln, 7. Nov. (Lecture)

Klaus Jäger: “Astrophysik mit dem HUBBLE-Weltraumteleskop”, Physikalisches Kolloquium der Universität Mannheim, 14. Apr.; “Astronomy/Physics meets Business – Job Careers for Astronomers and Physicists”, Naturejobs Career Expo, European Molecular Laboratory (EMBL), Advanced Training Centre, Heidelberg, 9. May

Knud Jahnke: “Galaxy Mergers in an Evolving Universe”, Hualien, Taiwan, 23. – 28. Oct. (Lecture); “Watching Galaxies Grow Up”, Ringberg Castle, 4. – 9. Dec. (Lecture); „Scaling relations between galaxies and their central black holes: Facts and fiction”, Univ. Southampton, USA, 4. May (Colloquium)

Lisa Kaltenegger: UMass Amherst, USA, Jan.; University of Bern, CH, March; “Spectral evolution of an Earth-like planet, Search for signs of life, Super-Earths and Life”, MPI für Radioastronomie, Bonn, Apr. (Lecture); Weltrauminstitute Graz, Österreich, Apr. (Lecture)

Alexander Karim: IRAM visitors Colloquium, IRAM, Grenoble, 8. March (Lecture); Ringberg workshop “Watching galaxies grow up”, Ringberg Castle, 5. Dec. (Lecture)

Hubert Klahr: “Role of turbulence in the formation of planets”, Turbulent Mixing and Beyond, Trieste, Italy, 21. – 28. Aug. (Review-Lecture); “The Nature and Role of Turbulence in Planet Formation: Magnetorotational and Baroclinic Instability”, KITP Workshop: “The Nature of Turbulence”, Santa Barbara, 7. Feb. – 3. June; “Rayleigh Benard Convection in Rotating Shear Flows”, KITP Workshop: “The Nature of Turbulence”, Santa Barbara, 7. Feb. – 3. June; “From thermal Convection in Protoplanetary Accretion Disks to Baroclinic Instability”, Ringberg Workshop on Geophysical and Astrophysical Fluid flow: Baroclinic Instability and Protoplanetary Accretion Disks, Ringberg Castle, 14. – 18. June (Review-Lecture); “The Role of Turbulence in Planet Formation”, Colloquium, Univ. Braunschweig, 10. Jan. (Colloquium); “The Role of Turbulence in Planet Formation”, Colloquium, Univ. Zürich, Schweiz, 14. Apr. (Colloquium); “Gravoturbulent Planetesimal Formation”, Colloquium at the National Astronomical Observatories of China (NAOC), Bejing, China, 30. Nov. (Colloquium); “The Role of Turbulence in Planet Formation – From colliding boulders to migrating planets”, Colloquium, KIAA Institute, Bejing Univ. Bejing, China, 1. Dec. (Colloquium); “Planet Formation from Dust to Planetesimals” Colloquium, Institute of Process Engineering (IPE), Chinese Academy of Sciences, Peking, China, 2. Dec. (Colloquium)

Oliver Krause: “Exoplanet Characterization Observatory – Instrumental concept”, Observatoire de Paris-Meudon, March (Lecture); “Light echoes of Core Collapse Supernovae”, Stockholm University, August (Lecture); “The Exoplanet Characterization Observatory EChO”, Department of Astronomy, Universität Göttingen, April (Colloquium)

Dietrich Lemke: “Infrarot-Weltraum-Teleskope – Entdeckungen im kalten Kosmos”, Jahrestagung der Deutschen Gesellschaft für Angewandte Optik, Ilmenau, 17. June (Lecture)

Hua-Bai Li: Star Formation through Spectroimaging at High Angular Resolution, ASIAA, Taipei, Taiwan, 20. – 24. June (Lecture)

Hendrik Linz: “NRAO Socorro Colloquium”, NRAO Socorro, New Mexico, USA, 4. March (Colloquium)

Andrea V. Macciò: “Dark matter distribution in galaxies” Tevpa conference (Lecture); “DE simulations with baryons” (Lecture); The dark Universe Conference; Physics Colloquium, Lancashire University, UK, 3. Apr. (Colloquium); Astronomy Colloquium, Trieste Observatory, Trieste, Italy, 24. May (Colloquium); TeV particle astrophysics conference, Stockholm, Sweden, 1. – 5. Aug. (Review-Lecture); The Dark Universe Conference, Heidelberg, 4. – 7. Oct. (Review-Lecture)

Luigi Mancini: "The search for extrasolar planets: successes, limits and future prospects", ASI Science Data Center, Frascati, Rome, Italy, 20. Dec. (Colloquium)

Nicholas Martin: Department of Astronomy, Universidad de Chile, Santiago, Chile, 1. Sep. (Colloquium); ETH, Institute for Astronomy, Zürich, Schweiz, 11. Oct. (Colloquium)

Klaus Meisenheimer: "The Impact of the VLTI on Galactic Nuclei and supermassive Black Hole studies", Workshop of the AGN/Gal. Center working group of the European Interferometry Initiative. Lissabon, Portugal 28. – 30. Nov. (Lecture)

Christoph Mordasini: Alexander von Humboldt Sino-German frontiers of science–symposium, Berlin, 21. Apr. (Lecture); Strange new worlds, NASA conference, Jackson Hole, USA, 16. Sep. (Lecture); Pas de deux GAIA workshop, Paris, 11. Oct. (Lecture)

Johan Olofsson: "Planet Formation in Action", IPAG institute, Grenoble, France, Apr. (Colloqium)

Natalie Raettig: "How Can the Baroclnic Instability Help Planet Formation", Weekly seminar of the Astronomy Department at the American Museum of Natural History, New York, USA, 15. March (Lecture)

Sarah Ragan: "HERSCHEL and high-resolution submillimeter studies of the early phases of cluster formation", IRAM, Grenoble, France, 22. Feb. (Gäste-Colloquium)

Hans-Walter Rix: Colloquium, Innsbruck, Austria, 1. Feb.; ESO Seminar, Munich, Sep.; Colloquium, IAP Paris, France, 9. Dec.

Gaël Rouillé: "Laboratory astrophysics in Jena: From spectroscopic characterization of large molecules and grains to low temperature chemistry", NWO Astrochemistry Workshop: Molecular Networks Connecting the Universe, Amsterdam, The Netherlands, 18. – 20. Apr. (Lecture)

Karin Sandstrom: ESO Santiago, 9. Sep. (Colloquium)

Eva Schinnerer: Star Formation in Galaxies: The HERSCHEL Era, Ringberg Castle, 19. – 24. June (Lecture); MW – The Milky Way in the HERSCHEL Era: Towards a Galaxy-Scale View of the Star Formation Life-Cycle, Rome, Italy, 18. – 23. Sep (Lecture); CEA/Saclay, Saclay, France, 14. Apr. (Colloquium)

Kasper Borello Schmidt: "Watching Galaxies Grow Up", Ringberg Castle, 5. – 9. Dec. (Lecture)

Dmitry A. Semenov: "Molecular Universe", IAU Symposium 280, Toledo, Spain, 29. May – 3. June (Lecture); Vienna Observatory, Vienna, Austria, 28. Nov. (Kolloqium); "The first 10 million years of the Solar System – a Planetary Materials Approach", 2. Colloquium of the SPP 1385, Mainz, 17. – 18. Oct. (Lecture)

Jürgen Steinacker: "The 3D barrier in star formation", Colloqium for Physics and Astronomy, University of Ghent, Belgium, 26. Jan; "The Coreshine-Effect", IPAG, Grenoble, France, 4. Nov. (Lecture)

Jochen Tackenberg: NRC Herzberg Institute for Astrophysics, Victoria, Canada, 20. Oct. (Colloquium)

Roy van Boekel: "Surveys & Simulations – The Real and the Virtual Universe" Annual Meeting of the Astronomische Gesellschaft, Heidelberg, 19. – 24. Sep.; (Lecture)

Remco van den Bosch: "Single and double black holes in galaxies", Conference, Ann Arbor, Michigan, USA, 22. – 25. Aug

Fabian Walter: Ringberg Workshop on Galaxy Formation, Ringberg Castle, April (Lecture); Colloquium Leiden, The Netherlands, June (Lecture); Ringberg Workshop on Star Formation in Galaxies: The HERSCHEL Era, Ringberg Castle, June (Lecture); CCAT Meeting, Cologne University, Oct. (Lecture)

Laura Watkins: Teneriffa, Spain, 22. July (Seminar)

Yujin Yang: "Theoretical Astrophysics Center Seminars", University of California Berkeley, USA, 7. Nov. (Seminar)

Xianyu Zhang: "First laboratory results with the LINC-NIRVANA high layer wavefront Sensor", LINC-NIRVANA MPIA Weekly Meetings, MPIA Heidelberg, 5. July (Lecture); "High order AO correction for LINC-NIRVANA", Galaxy and Cosmology Retreat, Neuwied, 17. Oct. (Lecture)

Svitlana Zhukovska: STSci, Baltimore, USA, 6. May (Lecture); Hauskolloqium, MPIA Heidelberg, 17. June (Lecture)

Talk Series

Friedrich Huisken: "Oxidative reactions of group IIA and IIIA elements in helium droplets", 482nd Wilhelm and Else Heraeus Seminar: "Helium Nanodroplets – Confinement for Cold Molecules and Cold Chemistry," Bad Honnef, 30. May – 1. June (Lecture)

Lisa Kaltenegger: SPASA summer school, Sao Paolo, Brasilien, Dec. (Lecture)

Dietrich Lemke: "Ballon-Astronomie", Universität Stuttgart, 20. Jan. (Lecture)

Andrea V. Macciò: "Structure formation in the Universe", Salerno University, Italy, March (Lecture)

Dmitry A. Semenov: "Astrochemistry with ALMA", ALMA Summer School, Bologne, Italy, 13. – 17. June (Lecture)

Arjen van der Wel: "Galaxy Evolution", ELIXIR meeting, CSIC, Madrid, Spain, 5. Oct. (Lecture)

Popular Talk Series

During the Lectures of "Uni(versum) für alle! Halbe Heidelberger Sternstunden" in the Universitätskirche/Peterskirche Heidelberg the following talks have been given:

Henrik Beuther: "Die Geburt der Sonne", 27. May

Christian Fendt: "Astronomische Zeitskalen: Von Millisekunden zu Gigajahren", 24. May

Roland Gredel: "Warum brauchen die Astronomen ein Teleskop mit 42 m Durchmesser", 17. May

Thomas Henning: "Warum beobachten wir die kältesten Objekte im Universum mit Infrarot-Teleskopen?", 14. Apr.
Tom Herbst: "Von 3 cm zu 42 m Durchmesser: Teleskope von Galilei bis 2020", 5. May
Klaus Jäger: "Astronomen als Detektive – wie wurde die Natur der geheimnisvollen Quasare entlarvt?", 29. June
Lisa Kaltenegger: "Wie kann man bewohnbare Planeten finden?", 13. July; "Gibt es Leben anderswo im Weltall?", 19. July
Martin Kürster: "Wie groß ist das Universum?", 9. May; "Warum funkeln die Sterne?", 17. June
Ralf Launhardt: "Der Lebensweg der Sterne", 24. June
Christoph Leimert: "Ebbe & Flut: Was haben die Gezeiten mit dem Mond zu tun?", 20. June
Dietrich Lemke: "Das todsichere Ende der Erde – wieviel Zeit bleibt uns noch?", 12. July; "Gefahren aus dem Welltall?", 20. July
Hans-Walter Rix: "Ist das Universum unendlich?", 2. May

Popular Talks

Kees Dullemond: "Kann es Leben auf anderen Planeten geben?", "Life Science Lab", Heidelberg, 11. Nov.
Christian Fendt: "Astronomische Perspektiven: Der Blick von der Erde – auf die Erde", Lecture beim "Studientag Perspektiven" am Hoelderlin-Gymnasium, Heidelberg, 12. July
Thomas Henning: "Von Staubscheiben zu extrasolaren Planeten – Die Entstehung von Planetensystemen", Wissenschaft im Rathaus, Dresden, 6. Apr.; "From Protoplanetary Disks to Planetary Systems", IUCAA, Pune, Indien, 23. Nov.
Friedrich Huisken: "Laborexperimente simulieren Bedingungen in interstellaren Staubwolken", Lange Nacht der Wissenschaften, 25. Nov.
Klaus Jäger: "Eine Legende hat Geburtstag – 21 Jahre Astronomie mit HUBBLE", Planetarium Mannheim 15. Feb.; "Geheimnisvolle Quasare – der Lösung eines Rätsels auf der Spur", DIDACTA-Messe, Stuttgart, 25. Feb.; "Scharfblick und Weitsicht – 400 Jahre Astronomie mit dem Fernrohr", Astronomietag, Planetarium Mannheim, 9. Apr.; "Eine Legende hat Geburtstag – 21 Jahre Astronomie mit HUBBLE", Rotary-Club, Buchen, 11. Apr.; "Geheimnisvolle Quasare – der Lösung eines Rätsels auf der Spur", Arbeitskreis Astronomie, Landesmuseum für Naturkunde, Bad Dürkheim, 1. Sep.; "Scharfblick und Weitsicht – 400 Jahre Astronomie mit dem Fernrohr", Lecture series "Faszinierendes Weltall" of the Förderkreis Planetarium Göttingen, Universität Göttingen, 18. Oct.
Knud Jahnke: "Die gigantischen Schwarzen Löcher in den Zentren von Galaxien", Astronomy of Sunday morning, MPIA Heidelberg, 24. July
Viki Joergens: "Braune Zwerge: Gescheiterte Sterne oder Superplaneten?", Bayrische Volkssternwarte Munich, 25. March
Lisa Kaltenegger: "Life in the universe?", Haus der Astronomie, Heidelberg, July; Lecture for pupils, MPIA, Nov.
Hubert Klahr: "Schöne neue Planetenwelten", Stuttgarter Zeitung – Leseruni, Hohenheim, 18. March
Oliver Krause: "HERSCHELs Blick ins Universum: Neues vom derzeit größten Weltraumteleskop", "Astronomie am Sonntag Vormittag", MPIA, June
Dietrich Lemke: "HERSCHEL – Entdeckungen im kalten Universum", Olbers-Gesellschaft, Bremen, 6. Dec.
Luigi Mancini: "The extrasolar planets", Torre Civica, Bientina (PI), Italy, 27. May
Markus Nielbock: "Finsternisse", Engadiner Astronomiefreunde, Hotel Laudinella, St. Moritz, Schweiz, 4. Jan.; "Die Sonne und andere Sterne", MaxIQ (Fördergruppe für hochbegabte Kinder), Willich, 11. Feb.; "Supernova-Lichtechos – Zeitreise zu einer Sternexplosion des 16. Jahrhunderts", Engadiner Sternfreunde, Hotel Laudinella, St. Moritz, Schweiz, 4. June; "Die Geburt von Sternen", Engadiner Sternfreunde, Hotel Laudinella, St. Moritz, Schweiz, 26. Nov.
Hans-Walter Rix: Planetarium Mannheim, 20. Oct.; Sternwarte Karlsruhe, Astronomische Vereinigung Karlsruhe e.V., 28. Nov.
Silvia Scheithauer: "Das James Webb Weltraumteleskop – Teil 2: Ein neuer Blick ins infrarote Universum", Kinderuniversität Bretten, 30. Nov.
Ana Uribe: "Planets and protoplanetary disks", Student's day at Heidelberg University, Heidelberg, March

Haus der Astronomie

Managing Scientist: Markus Pössel:

Scientists: Natalie Fischer (since 15. May), Olaf Fischer, Carolin Liefke, Alexander Ludwig (since 9. Sep.), Anita Mancino (since 1. Sep.), Tobias Schultz (since 9. Sep.), Cecilia Scorza, Jakob Staude

Student Assistants: Stephan Fraß (since 1. Oct.), Sophia Haude (since 1. May)

The House of Astronomy (HdA) is a center for astronomy education and public relations at Königstuhl. It was founded in late 2008 by the Max Planck Society and the Klaus Tschira Foundation. Other partners include the University of Heidelberg (in particular the Centre for Astronomy of Heidelberg University) and the city of Heidelberg. The Klaus Tschira Foundation is developer of the spiral galaxy-shaped building of the House of Astronomy, which opened in December 2011 ceremony. The Max Planck Institute for Astronomy is responsible for the content management of the house.

The HdA will carry the fascination of astronomy to the general public and in the schools, promote exchanges between scientists and the media and the general public make astronomical discoveries through simulations and research for Elementarization astronomical concepts understandable accessible as possible. In particular, the HdA is a forum for research and the promotion of scientific exchange, conducts educational work in the field of astronomical research (in particular through support of school projects, teacher training and the preparation of current astronomical research for the teaching of science and university education) as well as public relations and Media work in the field of astronomy and astrophysics.

Awards

Olaf Fischer was awarded the Hans-Ludwig Neumann Prize for Teaching and Learning 2011, the Astronomical Society.

Marcel Frommelt did research on youth with his work "Nutzungsmöglichkeiten einer Ballonsonde im Rahmen einer Mission zum Saturnmond Titan" the first Place in the regional competition in the division Nordbaden Earth and space sciences, 3 Won place in the state competition in Baden-Württemberg and the special prize mobile.

The Minister for Science, Research and the Arts of Baden-Württemberg, Theresia Bauer, has become the patron of the EU UNAWE project in Baden-Wuerttemberg. The Astronomical Society has become the patron of the EU UNAWE project in Germany.

Teaching Activities

Winter Term 2010/2011:

O. Fischer, C. Liefke, M. Pössel, C. Scorza: "Von unserem Sonnensystem zu extrasolaren Planeten" (Seminar for medium term)

Summer Term 2011:

N. Fischer: "Grundlagen der Astronomie für die Schule" (Lecture). Pädagogische Hochschule Heidelberg.

O. Fischer, C. Liefke, M. Pössel & Cecilia Scorza: "Astronomisches in den Schlagzeilen" (Seminar for medium term), Heidelberg University

Winter Term 2011/2012:

C. Liefke, O. Fischer: "Die Milchstraße" (Seminar for high school teacher), Heidelberg University

Service in Committees

Olaf Fischer is a member (Chairman since September 2011) of the Education Commission of the German Astronomical Society.

Cecilia Scorza is German coordinator of the "European Association for Astronomy Education", German Coordinator of EUNAWE program, a member of the IAU Education Commission and a member of the school committee of the Astronomical Society.

Jakob Staude is the editor of "Sterne und Weltraum".

The Haus der Astronomie is the German node of the "Eso Science Outreach Network" (C. Liefke, M. Pössel).

Further Activities

Olaf Fischer has supervised the development of 24 WIS materials for the upper and middle level car within the project "Wissenschaft in die Schulen!" (Cooperation with publishing Spektrum der Wissenschaft).

Carolin Liefke and Markus Pössel have served as part of a collaboration with the Hector Seminar Research Projects for gifted students, Markus Pössel plus two students of the "International Summer Science School Heidelberg".

Carolin Liefke has supervised the technical work of the student spectroscopy S. Oberholz Werner-Heisenberg-Gymnasium Bad Durkheim and the technical work Exoplanetentransits the student from S. Graf Nikolaus von Weis Gymnasium Speyer.

Markus Pössel and Carolin Liefke have a supervised internship (4 – 15 April).

Olaf Fischer, Cecilia Scorza, Marcel Frommelt, Tobias Schultz and Alexander Ludwig have a total of five interns supervised BOGy (14 – 18 March and 2 – 4 November).

Carolin Liefke has 2 search campaigns for the Pan-Starrs project-IASC (asteroid search with students) coordinated a total of 12 German students and supervised groups.

Olaf Fischer manages a degree thesis “Zur unterrichtlichen Verwertung von technischen und wissenschaftlichen Herausforderungen beim Sofia-Projekt” (until 20. June) and a thesis work on exoplanets. (since 7. Dec.)

Cecilia Scorza has a (provided by N. Christlieb, LSW) degree thesis on “Zustandsgrößen von Sternen und die Suche nach metallarmen Sternen” co-supervised (September – November 2011).

Cecilia Scorza and Marcel Frommelt have for the “MINT boxes” of the Baden-Württemberg Foundation MINT 15 boxes made on infrared astronomy for hire.

Natalie Fischer and Cecilia Scorza have developed and produced the EU UNAWE MINT Box “Adventure Astronomy – a journey through space for elementary students“ for the state of Baden-Württemberg, (in cooperation with Astronomieschule e.V.)

Natalie Fischer and Markus Pössel have presented the MINT boxes infrared astronomy and elementary school astronomy at the event “Mach MINT! Experimente zum Anfassen” at the Baden-Württemberg Stiftung in Stuttgart (17 October).

Cecilia Scorza and Alexander Ludwig have developed outreach materials for Mars Express, In cooperation with the EsoC, Darmstadt.

Cecilia Scorza writes the monthly sky preview for the “Rhein-Neckar-Zeitung”.

Conferences, Scientific, and Popular Talks

HdA-Events and cooperation events at the HdA:

Teacher training for the meeting of the Astronomical Society in Heidelberg, 23 Sep. (O. Fischer, C. Liefke).

Four Teacher Trainings on UNAWE MINT-Box “Abenteuer Astronomie – Eine Reise durch das Weltall für Grundschüler”, 19 Oct., 14 Nov., 16 Nov. and 9 Dec. (N. Fischer)

Students meeting at the Max-Planck-Day, 11 Nov. (O. Fischer, C. Liefke, M. Pössel, C. Scorza [Organisation])

Commemorative Colloquium for Jakob Staude, MPIA/HdA, 15. Nov. (K. Jäger, M. Pössel, A. M. Quetz, U. Reichert, u.a.)

Information day for partners and cooperation partners of the Haus der Astronomie, 25 Nov.

Information session for participants of 2011 German–Japanese Round Table, 1 Dec. (M. Pössel)

Official Opening Ceremony of the Haus der Astronomie, 16 Dec.

Interdisciplinary Teacher Training “Aufbruch zum Mars” for teachers from Baden-Württemberg, 19 Dec. (O. Fischer, C. Scorza, M. Pössel, T. Schultz, A. Ludwig)

Eight workshops for students in the lower, middle and upper school (C. Scorza, T. Schultz) with a total of 260 participants; four workshops for elementary school children (N. Fischer); Seven workshops for kindergartners (N. Fischer and A. Mancino) with a total of 270 participants.

Guided tours across the HdA-site and through the HdA for a total of about 360 participants, all year round (N. Fischer, O. Fischer, C. Liefke, M. Pössel, C. Scorza, J. Staude)

Reviews of / participation in external events:

3. Conference of NWT-Teachers, Heilbronn, 18 Feb. (C. Scorza)

Level of information and monitoring station, “Lange Nacht der Museen”, Planetarium Mannheim, 9 Apr. (C. Liefke, M. Pössel)

MPIA-Girls□ Day, 14 Apr. (O. Fischer, C. Liefke, C. Scorza, M. Pössel)

Student Program to reward the E-team by Mayor Dr. Eckart Würzner, 19 Apr. (O. Fischer, C. Liefke, C. Scorza, M. Pössel)

Workshop “Den Nachthimmel entdecken” for Teacher of the Stuttgart Region, 11 May, and as a training course for NwT-teachers at the Friedrich Schiller Gymnasium Marbach, 16 May (C. Scorza and O. Fischer)

Experiment stations and observation station to scientific experience days “Explore Science” of the Klaus Tschira Stiftung in Mannheim, 18 – 22 May (C. Liefke [Organisation], N. Fischer [Organisation], O. Fischer, M. Pössel, C. Scorza; in Cooperation with the Astronomieschule e.V.)

Teacher training at the training academy Biberach, 19 – 20 May (C. Scorza und O. Fischer)

Higher rate “Wir entdecken den Sternenhimmel” for gifted elementary school children, Hector-Kinderakademie, 26 May – 15 Dec. (N. Fischer)

Training “Sonne, Mond und Sterne” for educators in cooperation with the research station Heidelberg, 7 June – 8 Nov. (N. Fischer)

Level of information and monitoring station at the “Uni-Meile” (Anniversary celebration of the Heidelberg University), 25 June (N. Fischer, O. Fischer, C. Liefke, M. Pössel, C. Scorza)

Project Days spectroscopy at the Gymnasium Neckargemünd, 19 – 21 July (C. Liefke)

Astronomy Course "Sonne oder Treibhausgas. Wer ist verantwortlich für den Klimawandel?" of the Deutschen Schülerakademie in Rostock, 6 July – 24 Aug. (O. Fischer)

Workshop and lecture in the statewide teacher training Astronomy, Jena, 12 July (C. Liefke)

Astronomy Course "Aufbruch zum Mars – wir erforschen den roten Planeten" at the Science Academy Baden-Württemberg, Adelsheim, 26 Aug – 8 Sep. (O. Fischer, C. Scorza)

Teacher training "Aufbruch zum Mars" at the Sternwarte Sonneberg, 25 – 26 Sep. (O. Fischer und C. Scorza)

Teacher training for the HdA-DSI-Partner schools, 19 – 21 Sep. (C. Scorza)

Open Day of the European Southern Observatory (Eso), 15 Nov. (C. Liefke)

E-HOU-Teacher training at the Radio Observatory "Astropeiler", Stockert, 18 – 19 Oct. (C. Scorza und O. Fischer)

Teacher training "Blicke zum Sternenhimmel" at the Institute of Space Systems, University of Stuttgart, 24 Nov. (C. Scorza und O. Fischer)

Talks:

Natalie Fischer: "UNAWE-MINT-Box Abenteuer Astronomie – Eine Reise durch das Weltall für Grundschüler",Mach MINT!' Stuttgart, 17 Oct.; "Teacher training in Germany" and "Evaluation: Impact on Children", EU-UNAWE Project Manager Workshop, Leiden, 29 Nov.

Olaf Fischer: "Wir reisen zum Mars", Children's Academy Gera, 9 Nov.; "Wissenschaft in die Schulen", Commemorative Colloquium for Jakob Staude, MPIA/HdA, 15. Nov.

Carolin Liefke: "Stellare Flares", Starkenburg-Sternwarte, Heppenheim, 11 Jan.; "Aktivität von Sternen", Planetarium Mannheim, 15 March; "Pan-Starrs-IASC: Asteroid Search with pupils", 14. Kleinplanetentagung, Heppenheim, 18 June; "Welche Farbe hat eigentlich die Sonne?", Uni(versum) für alle, Heidelberg, 6 July and EsoC 23 Aug.; Lecture "Zum Besuch beim Very Large Telescope", Allgäuer Volkssternwarte Ottobeuren, 3 Sep.; "Das Haus der Astronomie", Regional Meeting Astronomy, Sternwarte Bellheim 8 Oct.; Lecture "Amateurastronomie in Germany", Sternwarte Neumünster, 5 Nov.

Anita Mancino: "Evaluation: Impact on Children", EU-UNAWE Project Manager Workshop, Leiden, 29 Nov.

Markus Pössel: "Kosmologie, Stephen Hawking und der Anfang des Universums", Diözesan-Akademie Stuttgart, 14 Jan.; "Die häufigsten Missverständnisse über Schwarze Löcher", Uni(versum) für alle, Heidelberg, 26 Apr.; "Wenn der Weltraum zittert: Astronomie with Gravitationswellen", Uni(versum) für alle, Heidelberg, "Gravitationswellen – oder wenn das All vibriert", DLR-Astro Seminar, Cologne, 24 May and Karl-Rahner-Academy, Cologne, 25 May; 9 June; "Das Universum expandiert – aber was heißt das?", Uni(versum) für alle, 27 June; "Woher kommen wir? Wohin gehen wir? Zwei Grundfragen aus astronomischer Sicht", Occupational Health Symposium, Erfurt 22 July; Splinter Meeting "Public Outreach in der Astronomie", Annual Meeting of the Astronomical Society, Heidelberg, 21 Sep.; "Schwarze Löcher für Anfänger und Fortgeschrittene", Planetarium Mannheim, 4 Oct. and Student internship at the MPIA, Heidelberg, 25 Oct.; "Das Haus der Astronomie", Commemorative Colloquium for Jakob Staude, MPIA/HdA, 15. Nov. .

Cecilia Scorza: "Das EUNAWE-Netzwerk live: Videokonferenz mit südafrikanischen Kindern", EUNAWE-Kick-off event, Brussels, 24 Apr."Gibt es Leben auf dem Mars?", Uni(versum) für alle, Heidelberg, 13 May; "Was ist eigentlich 'die Milchstraße?'", Uni(versum) für alle, Heidelberg, 10 June; "Educational resources from EUNAWE-Germany", EUNAWE-Workshop, Leiden, 28 – 30 Nov.

Publications

Fischer, O., C. Scorza: "Mars und Erde im Vergleich – Sinklöcher und Vulkane", Wissenschaft in die Schulen! 2/2011

Fischer, O.: "Radioteleskope – Konstruktionen mit dem "Parabel-Gen",Wissenschaft in die Schulen! 3/2011

Fischer, O.: "Tatort Schule – Spektroskopie erleben",Wissenschaft in die Schulen! 7/2011

Fischer, O.: "Das Sofia-Teleskop aus Sicht des Ingenieurs",Wissenschaft in die Schulen! 7/2011

Fuhrmeister, B., S. Lalitha, K. Poppenhaeger, N. Rudolf, C. Liefke, A. Reiners, J.H.M.M. Schmitt & J.-U. Ness: "Multi-wavelength observations of Proxima Centauri" in A&A 534, A133 (2011)

Liefke, C.: "In und über den Wolken – Das Internationale Teleskoptreffen ITT 2010" in Sterne und Weltraum 2/2011, S. 100–102.

Liefke, C.: "Fernerkundung und Kartografie im Sonnensystem",Wissenschaft in die Schulen! MS 3/2011

Liefke, C.: "Von Supernovae und Gezeitenschweifen – die Strudelgalaxie M 51" in Sterne und Weltraum 8/2011, S. 75–77.

Liefke, C.: "Die Flammenhülle von Beteigeuze" in Sterne und Weltraum 10/2011, S. 28–29.

Pössel, M.: "Ein Exoplanet aus einer anderen Galaxie" in Sterne und Weltraum 1/2011, S. 28–29.

Pössel, M.: "Das Haus der Astronomie in Heidelberg" in Astronomie und Raumfahrt im Unterricht 48, Ausgabe 3–4, S. 31–34.

Pössel, M.: "Einschläge ohne Rhythmus" in Sterne und Weltraum 11/2011, S. 36–39.

Scorza, C., N. Fischer:Abenteuer Astronomie. Eine Reise durch das Weltall für Grundschulkinder. 128 Seiten incl. Kopiervorlagen (2011)

Scorza, C.: "Verborgene Sterne aufspüren" in Spektrum NEO Nr. 1, "Unser Universum", S. 66–70 (2011)

Publications

In Journals with Referee System

Absil, O., J. B. Le Bouquin, J. P. Berger, A. M. Lagrange, G. Chauvin, B. Lazareff, G. Zins, P. Haguenauer, L. Jocou, P. Kern, R. Millan-Gabet, S. Rochat and W. Traub: Searching for faint companions with VLTI/PIONIER. I. Method and first results. Astronomy and Astrophysics 535, id. A68 (2011)

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