Max Planck Institute for Astronomy

Heidelberg-Königstuhl

Annual Report 2014

Cover Picture:
One of two of the molecular clouds studied by Kainulainen and colleagues: The Rho Ophiuchi cloud in the Milky Way. In the background, an ordinary image of the Milky Way; the inset map shows to what extent the light of background stars is dimmed as it passes through the cloud in question. Such maps form the basis of the three-dimensional reconstruction of cloud structure from which the astronomers derive their "recipe for star formation".
See Chapter II.7, page 38.

Credits: Column-density maps: J. Kainulainen, MPIA; Background: ESO / S. Guisard (www.eso.org/~sguisard)

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Max Planck Institute for Astronomy

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Preface

The first detailed surface map of a brown dwarf, showing cloud structures and thus the (highly inclement) weather of the failed star; a three-dimensional reconstruction of a slice of the distant universe at largest scales, using methods similar to medical applications of computer tomography; finding a fundamental law for the preconditions of star formation and showing the growth of dwarf galaxies by the accretion of even smaller galaxies: 2014 has been an exciting year for research at the Max Planck Institute for Astronomy (MPIA).

We can report excellent progress in instrumentation, as well. Two instruments with major MPIA contributions have successfully seen first light: The exoplanet hunter SPHERE, installed at ESO's Very Large Telescope in Chile, and the infrared wide-field camera PANIC at Calar Alto Observatory. As far as space missions go, Gaia, launched in late 2013, has begun observing, working towards its first data release in 2016.

Concerning organizational matters of importance to the institute, the collaborative research center SFB 881 "The Milky Way System" at the University of Heidelberg, in which MPIA is a partner, was approved for another funding period (2015-2018). The SFB, which is focused on "local cosmology" – learning more about galaxies from the one example, our Milky Way, that we can study in greatest detail – sits right at the interface of MPIA's two central research areas, planet and star formation and the evolution of galaxies.

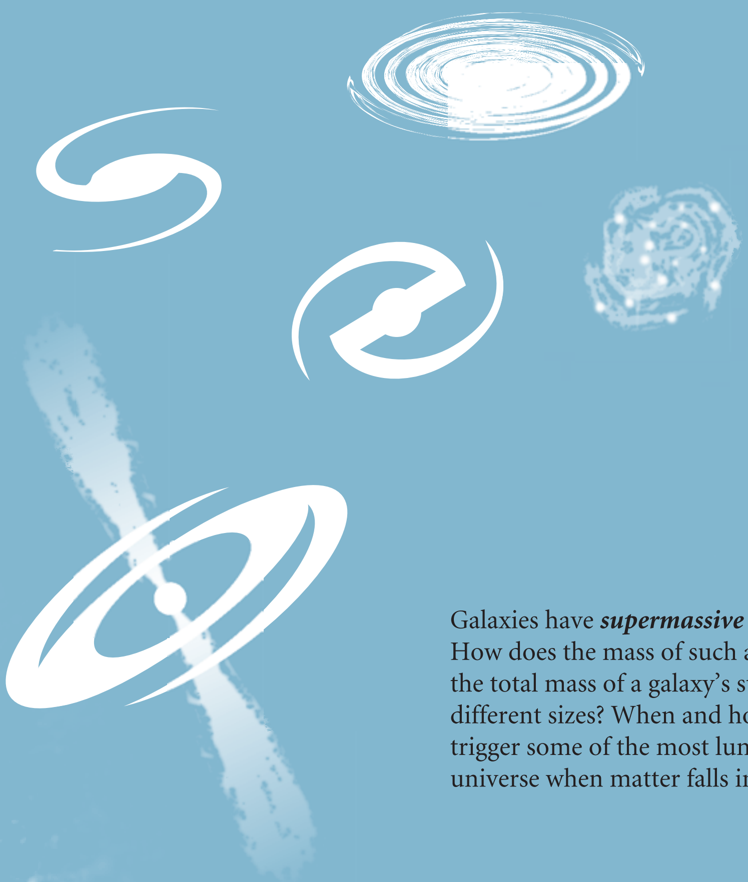
This annual report, intended both for our scientific colleagues and for the general public, is meant to provide in-depth information about the institute's activities. We present the year's scientific highlights as well as the current state of our instrumentation projects on the ground and in space, our activities in the area of outreach and academics as well as prizes and conferences.

Thomas Henning, Hans-Walter Rix

Heidelberg, November 2015

I. MPIA in a Nutshell

Our Fields of Research: Galaxies and Cosmology

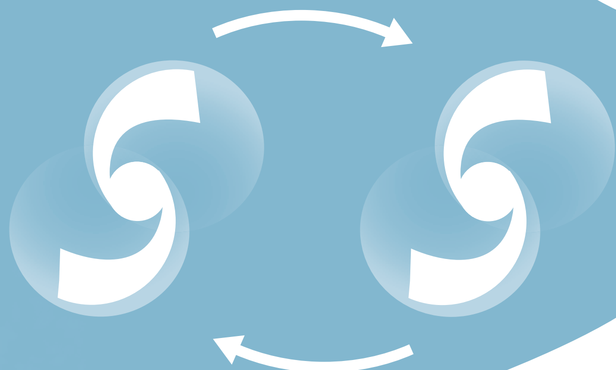


Galaxies come in many sizes and shapes. How do these differences arise? And what factors are responsible for how many stars a galaxy produces?

Our home galaxy, the ***Milky Way***, is a giant spiral galaxy with several hundred billion stars. In the Milky Way, we can study star and structure formation up close – and gather key data that can help us understand galaxy evolution.

Galaxies have ***supermassive black holes*** in their centers. How does the mass of such a black hole correlate with the total mass of a galaxy's stars – inspite of their totally different sizes? When and how do these black holes trigger some of the most luminous phenomena in the universe when matter falls into them, so-called quasars?

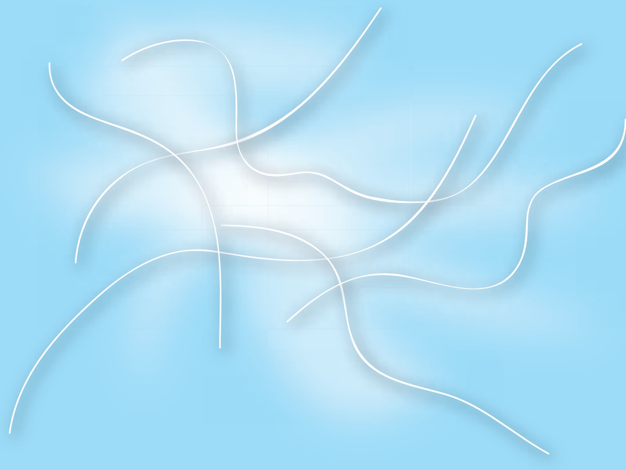
Galaxies grow as they merge with other galaxies, or swallow smaller galaxies. How do these growth processes work in detail? How do they influence the properties of different types of galaxies?



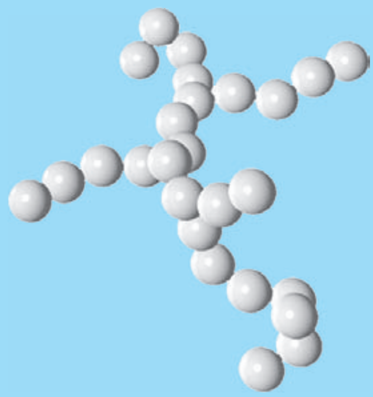
How are ***dark matter*** and hydrogen gas distributed on the largest ***cosmic scales***, across hundreds of millions of light-years? How is this distribution linked to the evolution of galaxies over the last billions of years? How did the complex structure of our universe arise from an almost perfectly smooth beginning?

Planet and Star Formation

Stars form when overdense regions in cold clouds of gas and dust collapse under their own gravity. Around a young star a swirling disk of matter condenses into ***planets***. How does this work in detail and how does this process produce the different kinds of planetary systems?



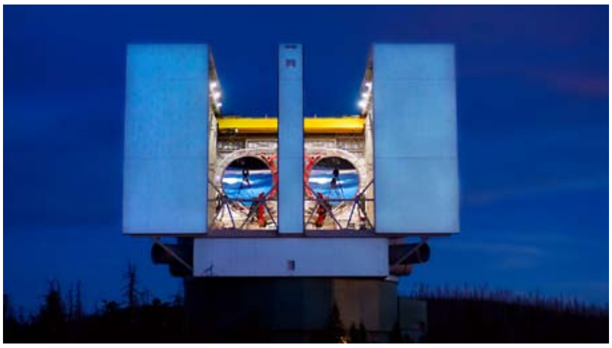
How do ***magnetic fields*** influence which clouds of the interstellar medium collapse to form stars? What is the role of turbulent motions within these clouds?



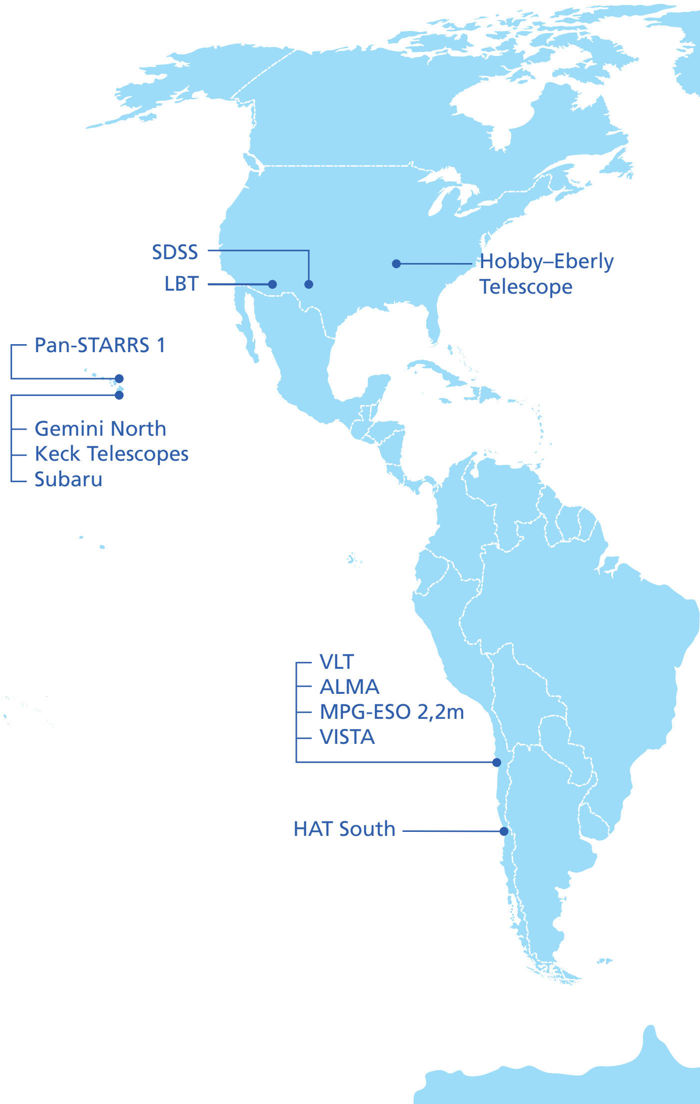
What are the ***stages of planet formation*** – from the first colliding ***grains of dust*** to objects thousands of kilometers across? What can laboratory experiments tell us about the properties of cosmic dust – and the ways to detect its properties?

Since 1995, astronomers have discovered nearly 2000 ***exoplanets*** (planets orbiting stars other than the Sun). What can these widely different planetary systems tell us about planet formation?

MPIA Telescopes all over the World



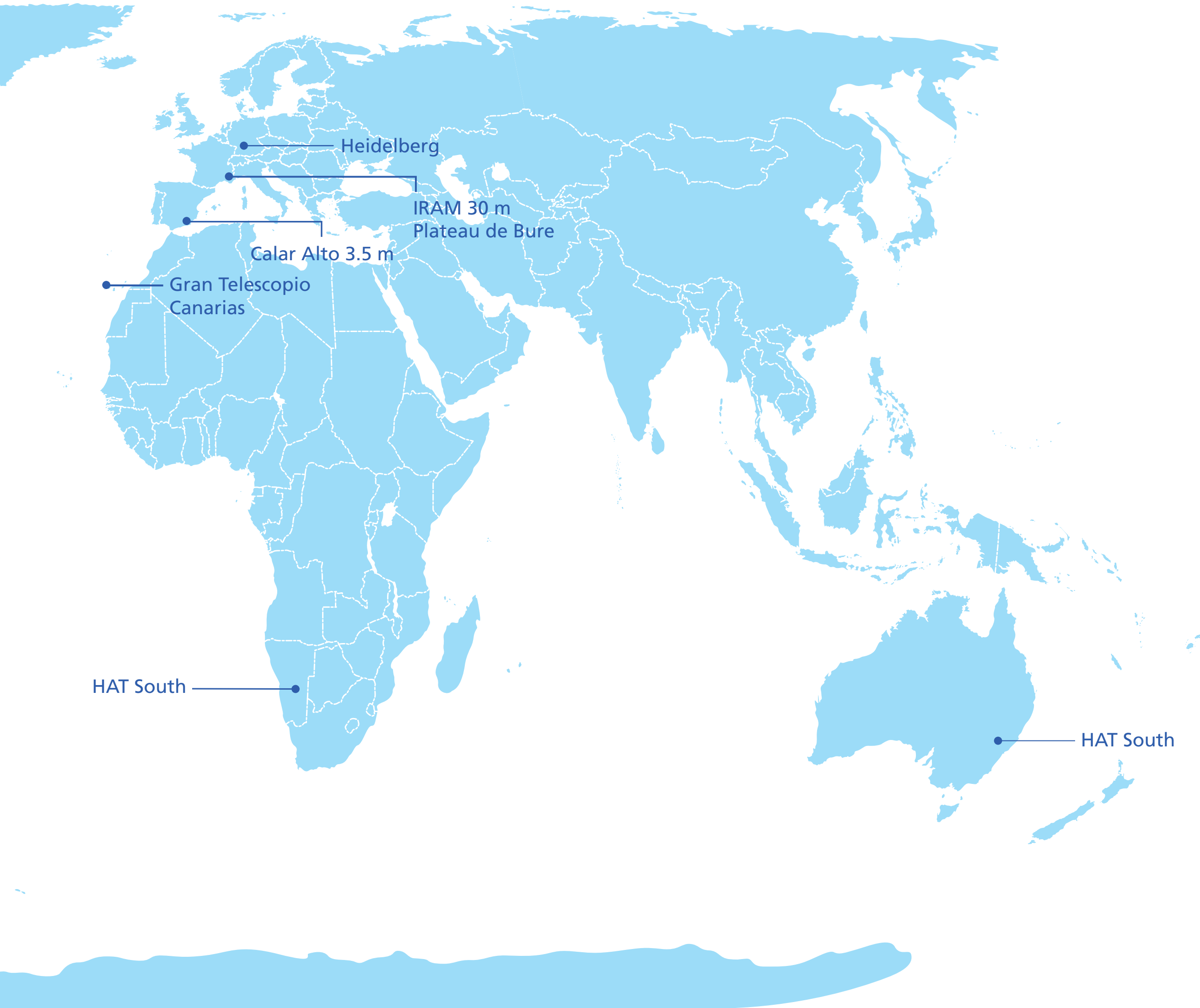
MPIA is part of the consortium operating the Large Binocular Telescope (LBT) on Mount Graham in Arizona. The LBT has two 8.4 meter mirrors on a single mount. For the LBT, our institute developed the double camera LINC-NIRVANA and the laser guide star system ARGOS.



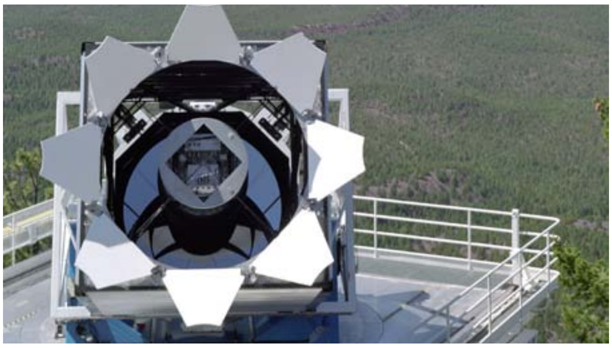
MPIA is involved in the construction of the instruments SPHERE, MATISSE, and GRAVITY for ESO's Very Large Telescope at Paranal observatory. The exoplanet hunter SPHERE was installed at the VLT in 2014, and has already taken its first observations.

At the Subaru telescope on Hawaii, an 8.2 meter telescope atop Mauna Kea, MPIA is a partner in the survey SEEDS. The survey is meant to produce direct images of exoplanets, and of the dust and gas disks that surround such planets.

MPIA is part of the PS1 Science Consortium, which operates the Pan-STARRS1 telescope on Hawaii. By repeatedly taking wide-field images of numerous regions of the night sky, PS1 is producing something akin to a movie of celestial goings-on.

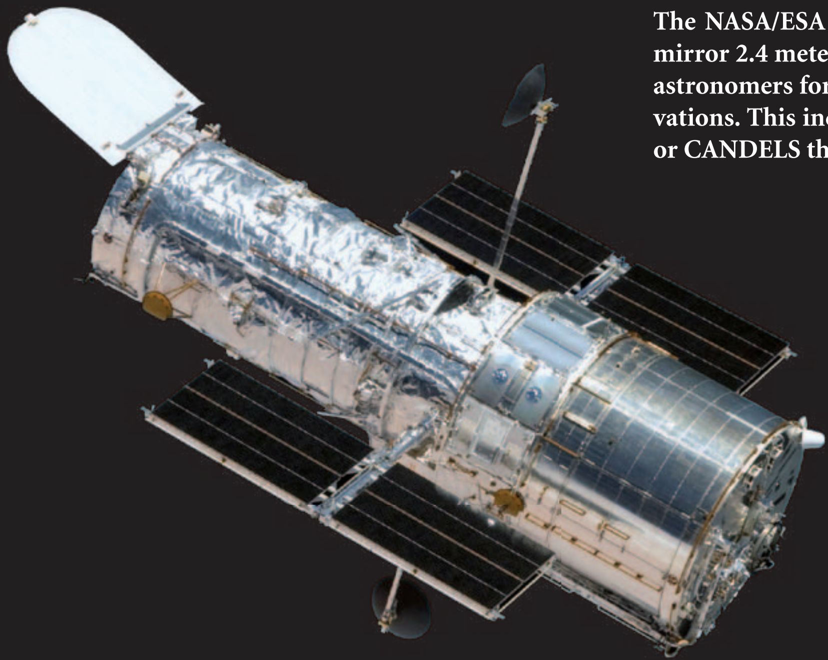


Calar Alto Observatory in Southern Spain was founded in the 1970s by MPIA, and is now operated as a joint German-Spanish research center. MPIA is involved in the construction of the instruments CARMENES and PANIC for Calar Alto telescopes.



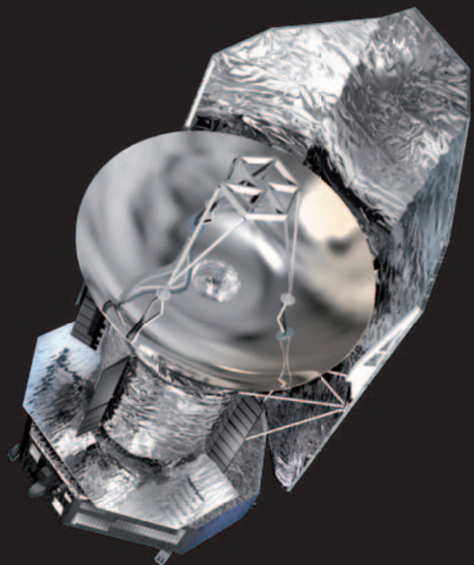
MPIA is a member of the Sloan Digital Sky Survey (SDSS), a spectroscopic survey using a 2.5 meter telescope in New Mexico. The survey gathers high-quality spectra of a large number of astronomical objects.

Space Telescopes



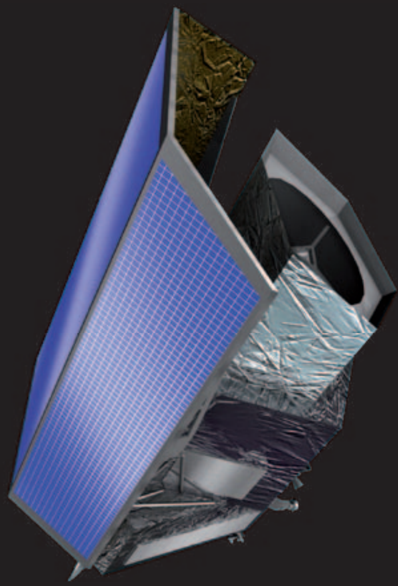
The NASA/ESA Hubble Space Telescope (with a main mirror 2.4 meters in diameter) has been used by MPIA astronomers for years for a variety of successful observations. This includes larger surveys such as COSMOS or CANDELS that involve MPIA researchers.

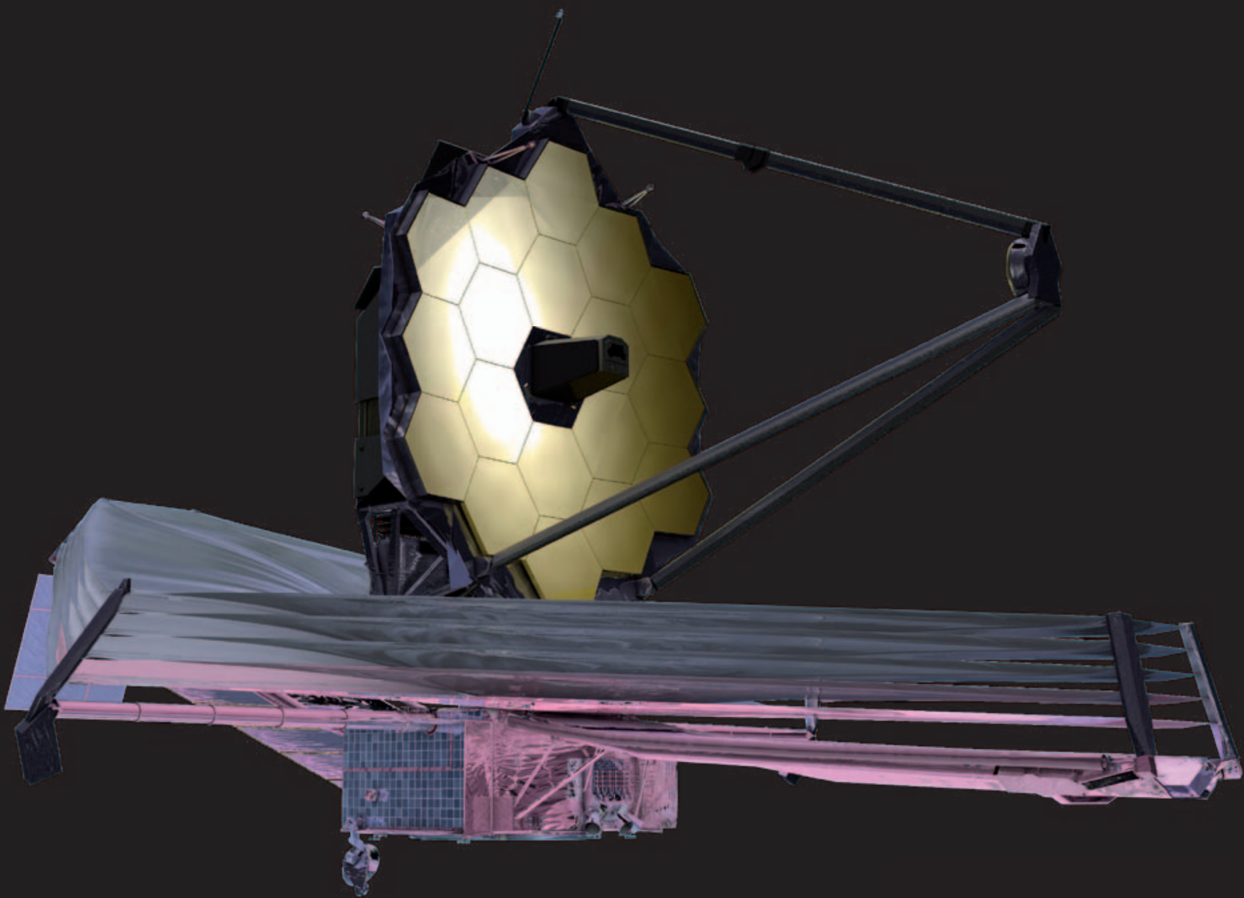
MPIA contributed to the construction of the ESA Infrared Observatory Herschel: We developed key components for the PACS instrument aboard the Herschel satellite, and were responsible for a number of observational programs undertaken with Herschel.



NASA's Spitzer Space Telescope is regularly in use for our researchers' observations. Using Spitzer, MPIA researchers have observed protostars inside clouds of dust, and detected active galactic nuclei from a time a mere billion years after the big bang.

For ESA's Euclid mission, which is slated for launch in 2020, MPIA scientist have developed calibration strategies and are contributing to the construction of the near-infrared spectrometer and photometer NISP. Euclid is set to answer fundamental questions about the nature of dark matter and dark energy.





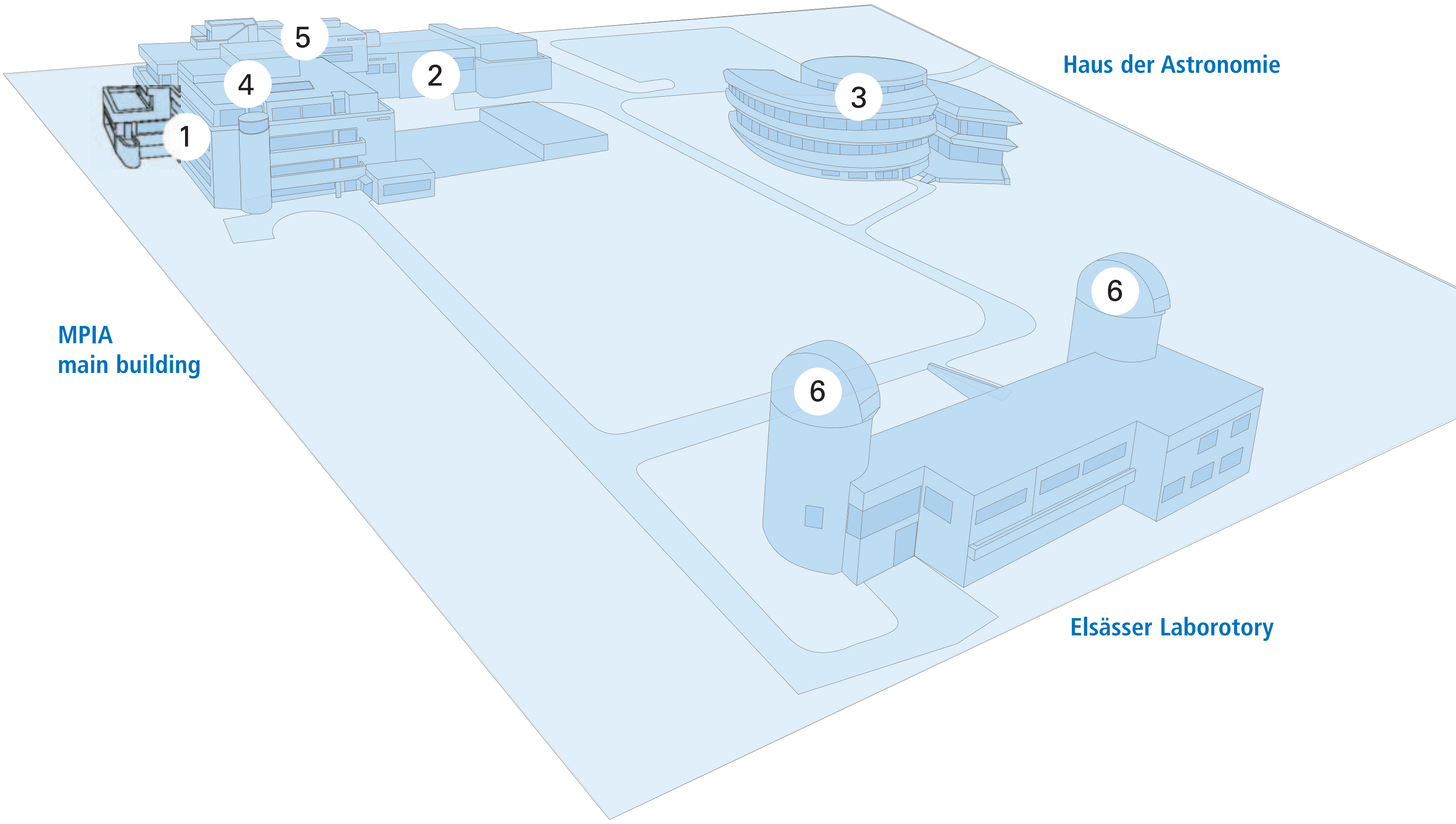
The James Webb Space Telescope (JWST, with a 6.5 meter mirror), the designated successor to the Hubble Space Telescope, is slated for launch in 2018. MPIA has contributed to two of the telescope's instruments: the mid-infrared instrument MIRI and the near-infrared spectrograph NIRSPEC.

Infrastructure

Specialized library offering nearly 9000 books and access to about 100 astronomical journals.

Experimental and assembly facilities including clean rooms for instrumentation.

Two lecture halls and seven seminar/workshop rooms, here: HdA auditorium.



IT infrastructure capable of handling large amounts of data from observations and simulations.

Workshops and construction facilities, here: precision mechanics workshop.

50 and 70 cm telescopes for testing and training purposes (here: 70 cm KING telescope).

MPIA in numbers

2

Scientific Departments
are at the core of the Max Planck-Institute for Astronomy: Planet and Star Formation (PSF) and Galaxies and Cosmology (GC)

1769

Terabyte
of data is produced by the Pan-STARRS1 survey, where MPIA is the major international partner. This corresponds to more than 375 000 DVDs.

310

employees
keep the institute running. 209 of those are scientists, including 67 junior scientists or long-term visitors, and 59 PhD students.

79760

CPUs
are humming along busily inside the Hydra supercomputer, which is used by MPIA astronomers for sophisticated simulations of the formation of planets and galaxies.

5

independent research groups
are part of our institute: two Emmy Noether groups (DFG), two Max Planck Research Groups and one group funded by the Alexander von Humboldt Foundation.

1200

refereed publications
based on data obtained with the ESA Herschel Space Observatory were published until the end of 2014. Most of the data used was provided by the PACS instrument, which was constructed with significant MPIA involvement.

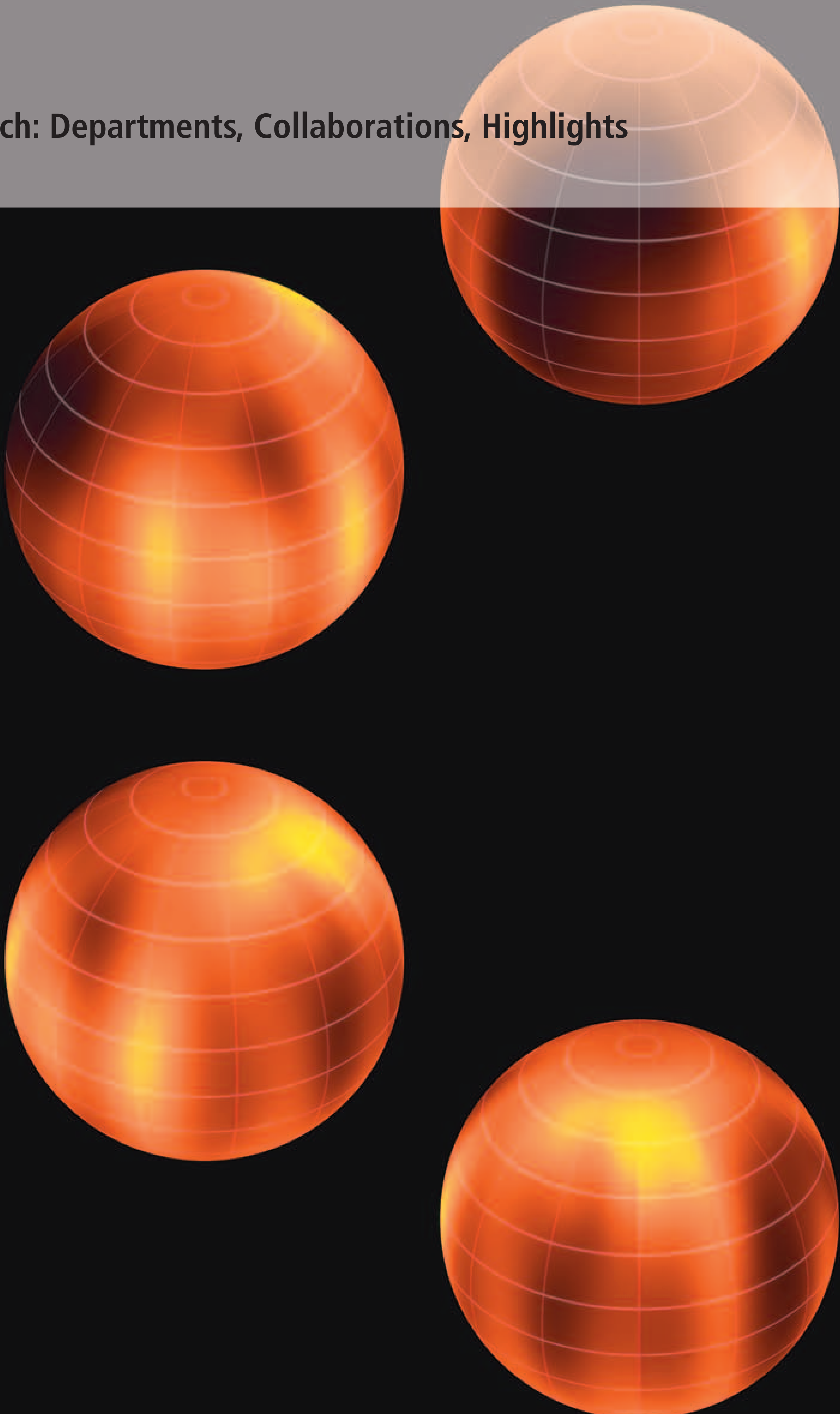
8.4

meters in diameter:
that is the size of each of the two mirrors of the Large Binocular Telescope in Arizona, the largest single telescope in the world. MPIA coordinates German involvement in the LBT.

39

meters
is the diameter of the mirror of ESO's European Extremely Large Telescope, currently under construction. MPIA is involved in the planning and construction of the two E-ELT instruments METIS and MICADO.

II. Research: Departments, Collaborations, Highlights



II.1

Planet and Star Formation – The PSF Department

The origin of stars and their planets

Star formation is a fundamental process in the universe. Stars shape the structure of entire galaxies, determine the chemical content of the cosmos, and create the necessary conditions for the origin of life.

Stars are born in the dense and cores of molecular clouds – giant clouds of cold gas, with masses thousands of times that of the sun – which become gravitationally unstable. As clouds collapse under their own gravity, some regions become sufficiently hot and dense for nuclear fusion to set in: a star is born. The formation of planets is a natural by-product of low-mass star formation. It takes place in protoplanetary disks of gas and dust surrounding nascent stars.

Fig. II.1.1: False-color image taken in three different »near-infrared colors« (JHK bands) of the galactic star formation region W49 with the LUCI instrument at the Large Binocular Telescope (LBT). Near-infrared radiation can pass through dust clouds almost unhindered. That is why observations like this can reveal details about star formation processes taking place deep within molecular clouds.

Researchers in the PSF department investigate a variety of open questions related to star and planet formation, combining infrared- and sub-millimeter observations with sophisticated computer simulations (magneto-hydrodynamics).

Observing the formation of stars and planets first-hand

Observational techniques in astronomy have made considerable progress over the past decade. The observing programs of the PSF Department cover a wide range of wavelengths, with a special emphasis on infrared, (sub-) millimeter, and radio observations.

Imaging with the Hubble Space Telescope and the wealth of data from the Spitzer Telescope and, between 2009 and 2013, from the Herschel space observatory is providing insight 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 interferome-

Credit: A. Bik / MPIA und Universität Stockholm

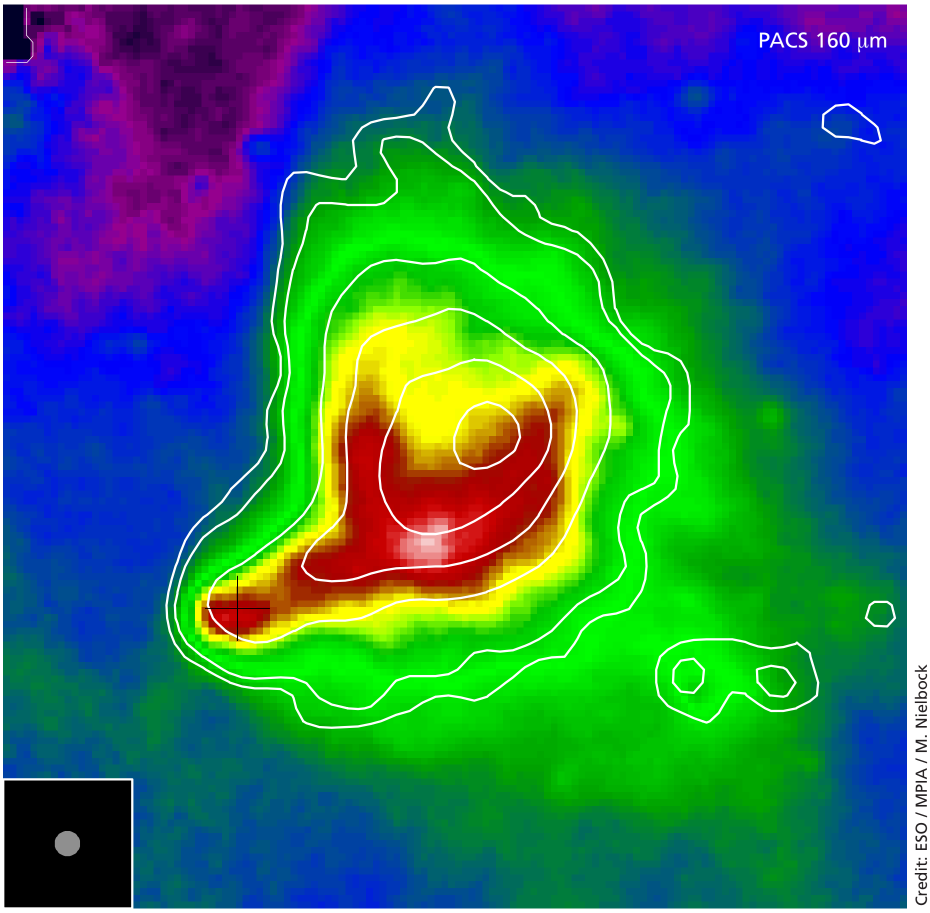


Fig. II.1.2: Map of the starless cloud core Barnard 68 (B68), obtained at an infrared wavelength of 160 µm. The observation was done with the PACS camera of the Herschel Space Observatory. The field-of-view is approx. 8'×8'. The color coding indicates the far-infrared emission to decline from the centre to the edge. By adding data obtained at infrared and millimeter wavelengths, it was shown that B68 exhibits a temperature gradient from about 20 K at the edge to about 8 K in the centre.

ters provide information about the disk structure and the evolution on spatial scales relevant to planet formation.

Gas evolution in disks is studied by high-resolution infrared spectroscopy and the accretion behavior – both the clumping of matter and its infall onto the disk – by multi-object spectroscopy.

Understanding masses and multiplicity

One of the central questions of star formation concerns what astronomers call the initial mass function (IMF): How probable is it that a collapsing cloud will form low-mass stars or high-mass stars? More specifically: How does the probability for the formation of a star of mass M depend on M? And which properties of the cloud determine the outcome in terms of mass? Open key questions concern the roles of magnetic fields and of turbulence in controlling the onset of star formation – with direct consequences for the initial (sub-)stellar mass function.

In general, collapsing clouds will fragment to form binary systems or multiple stellar systems in one go. On the high end of the mass scale, the formation of very massive stars takes place in clusters, which makes for exceedingly complex star formation environments. The rapid evolution of massive protostars and the associated energetic phenomena provide an enormous challenge in identifying the formation path of massive stars.

Dynamical interactions in multiple systems may also be a crucial factor for the formation of objects with masses too low to become real stars: Brown Dwarfs, first detected in 1995. How do Brown Dwarfs form? Are young substellar objects also surrounded by disks and associated with outflows? How many of these objects are formed as part of binary systems and what are their masses? What are the compositions of their atmospheres? These are just some of the questions under investigation by PSF Department scientists.

A peak 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 emit

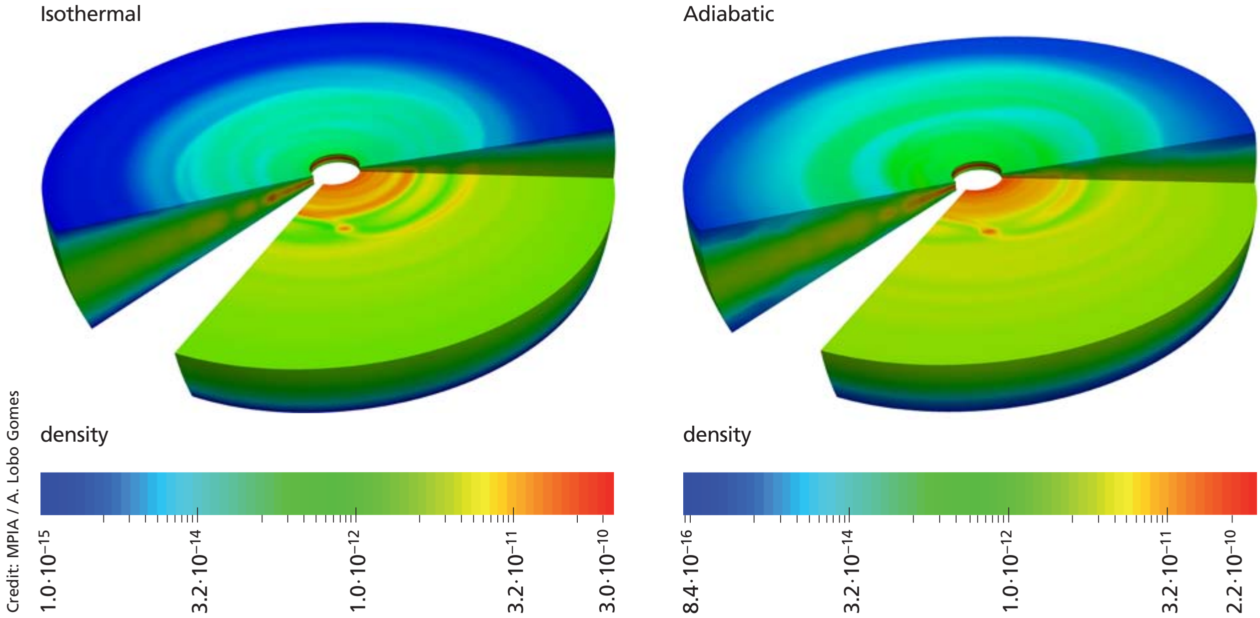


Fig. II.1.3: Simulations of a Jupiter-mass planet interacting with its parent disk. The planet is located at 5 AU. The results show the planet-disk system after 23 planetary orbits. The three images show three different models using different simplifications: Left, a locally isothermal model, where the temperature varies with the radius, but not with time. Center, an adiabatic model where temperature is allowed to vary over time, but a simplified equation of state (ideal gas) is used. In the first two models, there is no dust. The third model, to the right, does include dust as a thermal source, which allows gas to be heated by the dust's thermal radiation and, more importantly, to cool as the dust radiates away energy into space. The different model assumptions lead to different consequences. Notably, the mid-plane gap is carved out faster for the locally isothermal case than for the others. But in this case, the planet mostly does not affect the disk atmosphere, whereas in the adiabatic and dust/radiation cases, a gap is also visible in the upper layers of the disk.

what amounts to a thermal glow, becoming visible at near- and mid-infrared wavelengths. Even later, the nascent stars disperse their cocoon of dust and gas, and become visible at optical wavelengths in visible light.

Due to basic laws of mechanics (namely the conservation of angular momentum), the accretion of matter onto the central protostar happens predominantly via a circumstellar disk. Disks around T Tauri stars – young stars with a mass of up to 3 solar masses – are natural birthplaces for planetary systems. Our own solar system formed from just such a disk about 4.5 billion years ago.

While the protostar still accretes matter from the surrounding disk, some of the matter is ejected perpendicularly to the disk – both in the form of outflows of molecular gas and in the form of ionized jets. Direct observations of such disks and the associated phenomena can provide insight both into the formation of our own solar system and into the diversity of planetary systems in general.

Observing from the ground and from space

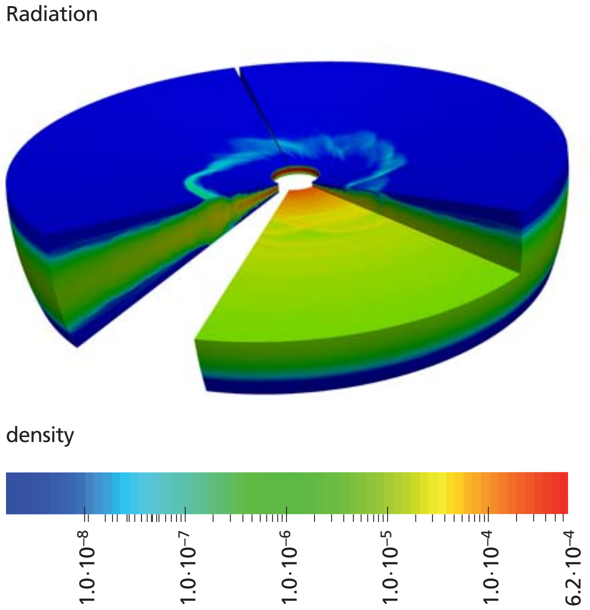
One of the goals of the PSF Department is to understand the earliest phases of stars both in the low and the high stellar mass regime. With space observatories such as Spitzer, the Hubble Space Telescope, and Herschel, as well as ground-based infrared and (sub-)millimeter telescopes, PSF researchers detect and characterize massive protostars and their subsequent evolution. Extensive experience in the use of submillimeter facilities has also prepared the department for observations with the new Atacama Large Millimeter/Submillimeter Array, ALMA.

Presently, the department is strongly involved in the preparation of projects in the field of star formation and protoplanetary disks for the James Webb Space Telescope, JWST, the designated successor of the Hubble Space Telescope. As a member of the consortium for the JWST instrument MIRI, we have access to guaranteed observing time for that instrument.

Planet formation and the search for exoplanets

With the detection of the first extrasolar planets in 1995, the study of planet formation in protoplanetary disks entered a new phase. Suddenly, instead of a single example for a planetary system – our own solar system – astronomers had dozens, then hundreds, now nearly 2000 such systems to examine, compare and contrast.

PSF astronomers have started new observing programs to search for extrasolar planets through direct imaging, the transit technique, and radial velocity observations of objects discovered with the Kepler space telescope. The HATSouth transit network with its three stations in Chile, Australia, and Namibia is returning a flood of new discoveries.



With the new planet finder instrument SPHERE, where MPIA is the Co-PI institute, we are presently embarking on a large exoplanet direct imaging survey. In addition, this instrument is returning images of planet-forming disks with unseen details, from rings to spiral arms, which point to complex dynamics and planet-disk interactions.

The department is also developing radiative transfer codes, which simulate the way that light and other electromagnetic radiation travel, e.g. through the interior and atmosphere of a star or planet. These codes can be used for studying planetary atmospheres and for characterizing their transmission and emission spectra, as they would be measured by telescopes on the ground or in space.

The department actively participates in the planet search program SEEDS with the Subaru telescope on Mauna Kea (Hawaii) and the LEECH program at the Large Binocular Telescope (LBT) on Mount Graham (Arizona).

Star and planet formation in a computer

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. Multidimensional 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.

Linking the cosmos and the laboratory

A better understanding of the microphysical processes in the dust and gas of star formation environments, as well as their observational signatures, requires dedicated laboratory studies. Such a laboratory astrophysics unit is part of the PSF 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 of molecules, especially polycyclic aromatic hydrocarbons (PAHs) as an important class of organic molecules found in astronomical settings in the gas phase. It also studies the formation pathways of small particles and their interaction with molecular ice layers.

Linking the cosmos with laboratories of another kind altogether, namely those of our colleagues in the life sciences, is the aim of another initiative: the Heidelberg Origins of Life Initiative (HIFOL) recently established by the PSF department in collaboration with other scientific institutes in Heidelberg.

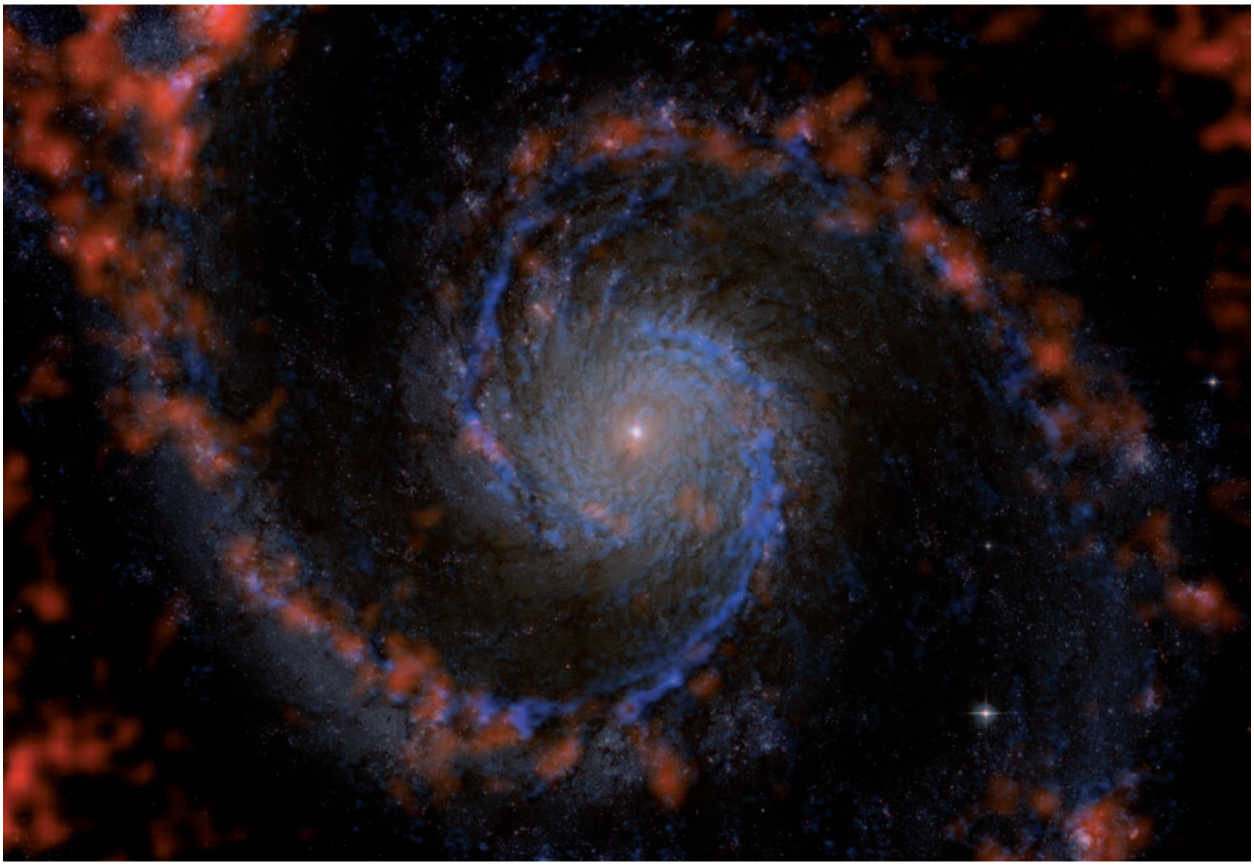
Galaxies and Cosmology – The GC Department

How the universe became interesting

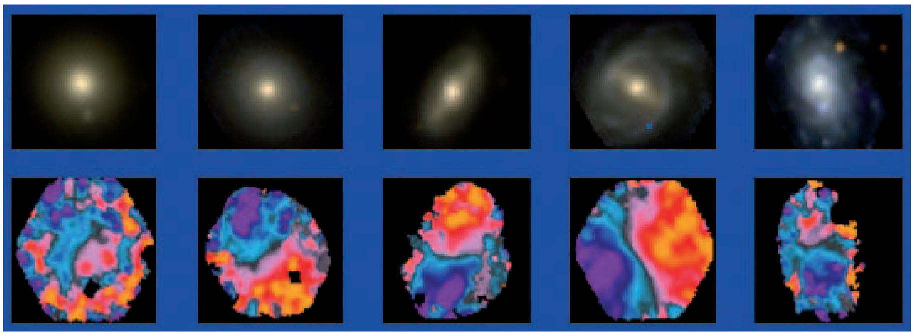
Shortly after the Big Bang, the universe was almost perfectly homogeneous and simple, that is: both elegant and boring. In stark contrast, the present cosmos exhibits a rich hierarchy of structures spanning a wide range of physical scales: from the filamentary distribution of galaxies known as the cosmic web down to galaxies, clusters of stars and individual stars and their planets. It is this structure that makes our universe interesting, yet also complex. The formation of all the large-scale structure appears to be driven by gravitational instabilities – by the ubiquitous influence of gravity, of matter pulling itself together, large structures collapsing and contracting. On the scales of galaxies, a plethora of other physical effects come into play.

To understand quantitatively how such structure arose in an expanding universe, however, current models need an unusual extra ingredient: Dark matter, which possesses mass, and hence gravitational attraction, but does not interact at all with electromagnetic radiation. The specific nature of this dark matter has yet to be understood. To make things worse, the expansion of the universe is observed to be accelerating, which forces astronomers to postulate an even more exotic ingredient: dark energy, which acts as a form of repulsive force.

Fig. II.2.1: Molecular hydrogen in the Whirlpool Galaxy M51. The blueish features show the distribution of hydrogen molecules in M51, the raw material for forming new stars. The PAWS team has used this data to create a catalogue of more than 1,500 molecular clouds. The reddish structures show the distribution of hydrogen atoms. The background is a color image of M51 by the Hubble Space Telescope. Superimposed in blue is the CO(1-0) radiation emitted by carbon monoxide (CO) molecules, as measured for the PAWS study using the millimeter telescopes of the Institut de Radioastronomie Millimétrique. The CO molecules are used as tracers for molecular hydrogen. The red structures show the HI line emissions of atomic hydrogen.



Credit: PAWS team/IRAM/NASA HST/T. A. Rector (University of Alaska Anchorage)



Quelle: Obere Reihe: SDSS | Untere Reihe: CALIFA-Team

Abb. II.2.2: The CALIFA survey, whose second data release was published in October 2014, provides unique spectral information on more than 200 nearby galaxies. Upper row: small pictures of five specimen of the sample of galaxies. Lower row: color-coded velocity maps of the same galaxies based on the CALIFA spectra. Blue clors show motion towards the observer, reddish colors correspond to the other direction.

There are places throughout the Universe where dense dark matter concentrations arise from gravitational instability and where consequently normal matter is distilled, so that stars from dense gas clouds: these places we call galaxies, and they arguably form the centerpiece (at least in physical scale) of the overall hierarchical structure of the cosmos.

Order in the realm of galaxies

Galaxies exist over a vast range of physical scales: they vary by many orders of magnitude in their stellar masses, in their rate of producing new stars or in the mass of the black holes at their very centers, and their sheer physical size.

Yet, as Edwin Hubble realized already 80 years ago, these »island universes« are not as varied in their appearance and structure as the laws of physics would allow. Observations, particularly those made over the last 15 years, have confirmed this in ever greater detail: Only a small fraction of the possible combinations of galaxies' characteristic quantities (stellar masses and ages, size, central black hole and more) 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 mass is proportional to the galaxy's spherical distribution of stars (»bulge«) inspite of the vast difference in size between the two structures (a factor of roughly ten millions). While spiral galaxies are the most common kind of galaxy, none of the most massive galactic specimens is of this type.

All this means that the »realm of galaxies«, to use Hubble's expression, exhibits a high degree of order. How did this order develop from the random mass fluctuations existing after the Big Bang? That is the fundamental question of galaxy formation and a central issue of cosmology.

Why no greater variety of galaxies?

There are three broad lines of explanation for the limited variety in the zoo of galaxies. Either, observed galaxies represent the only configurations that are dynamically stable over long times. If each galaxy spends a long time in a stable state, and a very brief time only in a transition state, then with astronomical observations at an essentially random moment in cosmic time (namely now), we are unlikely to catch more than a few (if any) galaxies in transition.

Alternatively, it is possible that the initial conditions of our universe only permit the formation of the galaxies we see. Finally, it is conceivable that galaxy formation is a highly self-regulating process that, regardless of initial conditions, can only result in a very limited set of outcomes – namely those combinations of properties that we actually observe.

Current research suggests that all three aspects may play a role.

Asking the right questions

The fundamental questions raised here inform numerous projects currently undertaken by researchers in the GC department. As always, the key to success lies in transforming fundamental into specific questions, which can be addressed using current tools and methods.

A number of these questions concern the broader aspects of galaxy formation: What is the state of the intergalactic medium – the extremely rarefied gas in the space between galaxies, where most of the atoms in the universe reside? How did gas get from the cosmic web into galaxies, there to be processed into new stars? Or, to bring up a more general question about the relationship between galaxies and dark matter's cosmic web: Which kinds of galaxy reside in dark matter halos of different size?

The process of star-formation on the scale of galaxies must be the key to understanding why galaxies look the way they do. When, how and how efficiently did gas in galaxies get converted into stars? The when, can be addressed by looking at distant galaxies, whom we see at an earlier epoch – because the speed of light is not infinite. The how can be addressed by mapping the gas (the fuel for star formation) and the star-formation itself in great detail in closer galaxies.

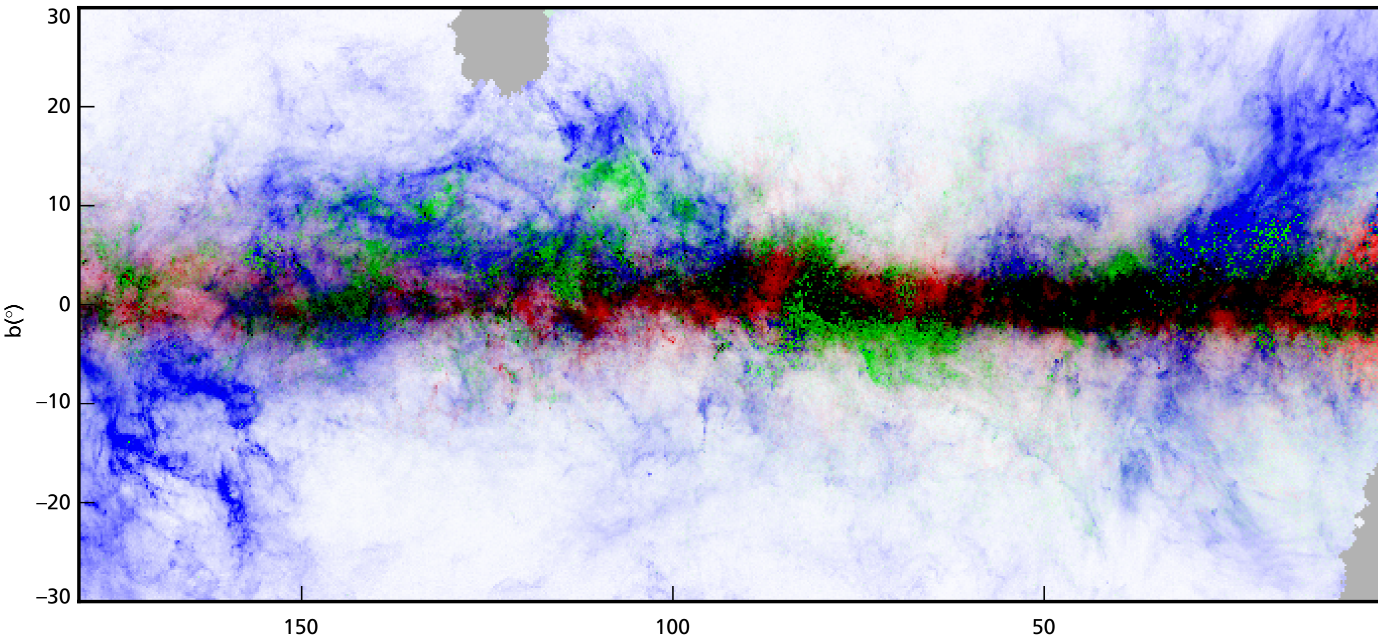


Fig. II.2.2: The 3D distribution of dust in the Milky Way (false color image). Exquisite high-resolution detail is obtained through the use of optical and near-infrared observations of almost a billion stars surveyed by Pan-STARRS1 and 2MASS. Multi-color photometry is used to estimate the reddening and distance to each star individually, which then allows for the 3D map to be determined. Dust within 630 pc (2050 light-years) is colored blue, between 630 pc and 2 kpc (6520 light-years) green, and beyond 2 kpc red. Each color plane saturates at 1 magnitude E (B-V). Grey areas: no data.

Another area of particular interest to MPIA concerns the central black holes of galaxies: Why is it possible to predict the properties of the central black hole from a galaxy's overall properties? And how did the central black holes in galaxies form and grow in the first place?

Most galaxies are so far away, that we cannot study their stars – their central and defining ingredients – individually. Yet, the chemical composition and the orbits of individual stars hold clues to when and where they were formed. Looking at stars individually, mostly in our own galaxy, can therefore test the understanding of galaxy formation processes in absolutely unique ways. But it remains a challenge ahead to make the Milky Way a Rosetta Stone of galaxy formation. In particular, this requires learning all we can about the individual and population properties of stars, from spectra and from the ongoing Gaia space mission.

Tackling the questions: From observations to simulations

In order to tackle these questions, the GC department follows a three-pronged approach. On the one hand, we study galaxies in the present day universe, including our own Milky Way, making the most of the level of details afforded by observations in our direct cosmic neighborhood.

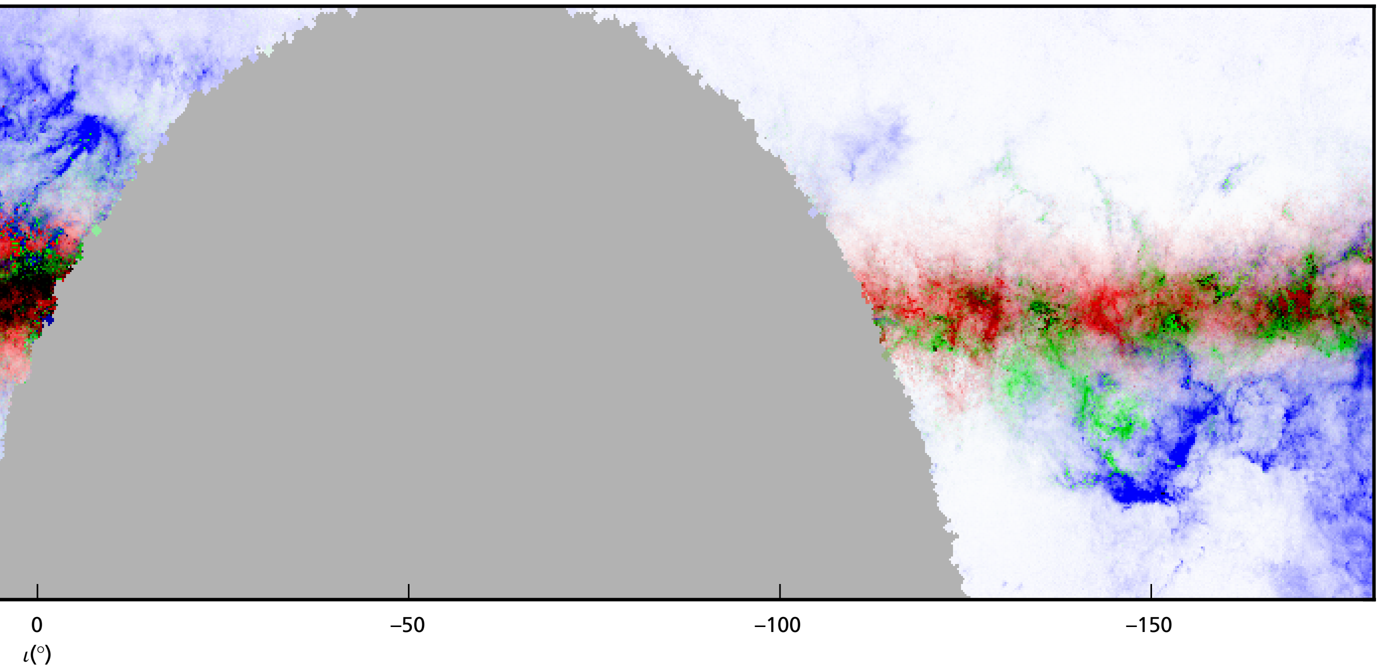
On the other hand, we study galaxies at earlier cosmic epochs directly by observing very distant objects (corresponding to high cosmological redshifts z); after all, astronomy always means observing the past: When light from a distant galaxy takes, say, 9 billion years to reach us, our present observations show us that galaxy as it was 9 billion years ago, affording us a glimpse into the distant past.

Finally, we compare our observations with physical models. This strategy requires diverse observational capabilities: survey telescopes to obtain large samples of cosmic objects, the largest available telescopes for sheer photon collecting power to examine faint sources, and techniques such as Adaptive Optics and interferometry in order to achieve high spatial resolution. Comprehensive studies of galaxy evolution also require observations across the whole of the electromagnetic spectrum from X rays to radio wavelengths.

Collaborations and initiatives

MPIA is leading a number of major, global observing programs to tackle theses questions: these range from deep fields with ALMA to find dense gas at high redshifts to large programs at the VLT and Keck to study the intergalactic medium and a VLT legacy survey to study the physics of high-redshift galaxies.

But we are also leading large programs using the VLA of the National Radio Astronomy Observatory in New Mexico, US, as well as IRAM's Plateau de Bure Interferometer in the French Alps to map gas in nearby galaxies.



Credit: Green et al. 2014, Schlafly et al. 2014 und Green et al. 2015 (submitted)

Extensive spectroscopic surveys of nearby galaxies map their stars' kinematics to reveal their dynamical structure and the nature of their central black holes.

MPIA is playing a leading role in making 3D maps of the Milky Way with the PS1 survey and Gaia, as well as in large spectroscopic surveys to understand our Galaxy's prehistory.

Finally, MPIA is leading the near-infrared photometry effort on ESA's Euclid mission, which will elucidate the most puzzling aspects of physics in the cosmos: the nature of dark energy.

II.3 International Networking

Scientific Initiatives

Science is a cooperative venture, and large-scale projects are usually tackled by more than one institute: in larger consortia or as a cooperative project between selected institutes. MPIA is an integral part of the international astronomy landscape and takes part in a number of key initiatives.

PanSTARRS 1 Sky Survey

The PS1 Science Consortium funds the operation of the Pan-STARRS1 telescope on Mount Haleakala in Hawaii. The telescope features the largest digital camera in the world. It makes repeated scans of the sky in order to provide time-series data of astronomical phenomena - a »movie« of the night sky, ideal for discovering transient phenomena. The consortium consists of astronomers from 10 institutions from four countries, including MPIA.

Sloan Digital Sky Survey IV

MPIA is a member of the Sloan Digital Sky Survey IV (SDSS), a spectroscopic survey using the Sloan Foundation 2.5-m-Telescope at Apache Point Observatory. Previous SDSS have revolutionized astronomy, providing quality spectroscopic data in unprecedented amounts and enabling statistical analyses that previously would have been impossible.

Collaborative Research Center 881: The Milky Way System

MPIA is part of the Collaborative Research Center 881 at the University of Heidelberg, which is funded by the German Science Foundation (DFG). SFB 881 examines various properties of our home galaxy to obtain a better understanding of its structure and evolution, as well as of the evolution of galaxies in general.

Heidelberg Initiative for the Origins of Life

The Heidelberg Initiative for the Origins of Life brings together researchers from astrophysics, geosciences, macromolecular chemistry, statistical physics and life sciences from the Max Planck Institute for Astronomy, the Max Planck Institute for Nuclear Physics, the Heidelberg Instutute for Theoretical Studies, and the University of Heidelberg in order to further our understanding of the origins of life in the universe.

DFG Priority Program SPP 1573: The interstellar medium

MPIA takes part in the German Science Foundation's SPP 1573, which is dedicated to research on the interstellar medium: the dilute mixture of charged particles, atoms, molecules and dust grains filling interstellar space.

International Max Planck Research School »Astronomy and Cosmic Physics«

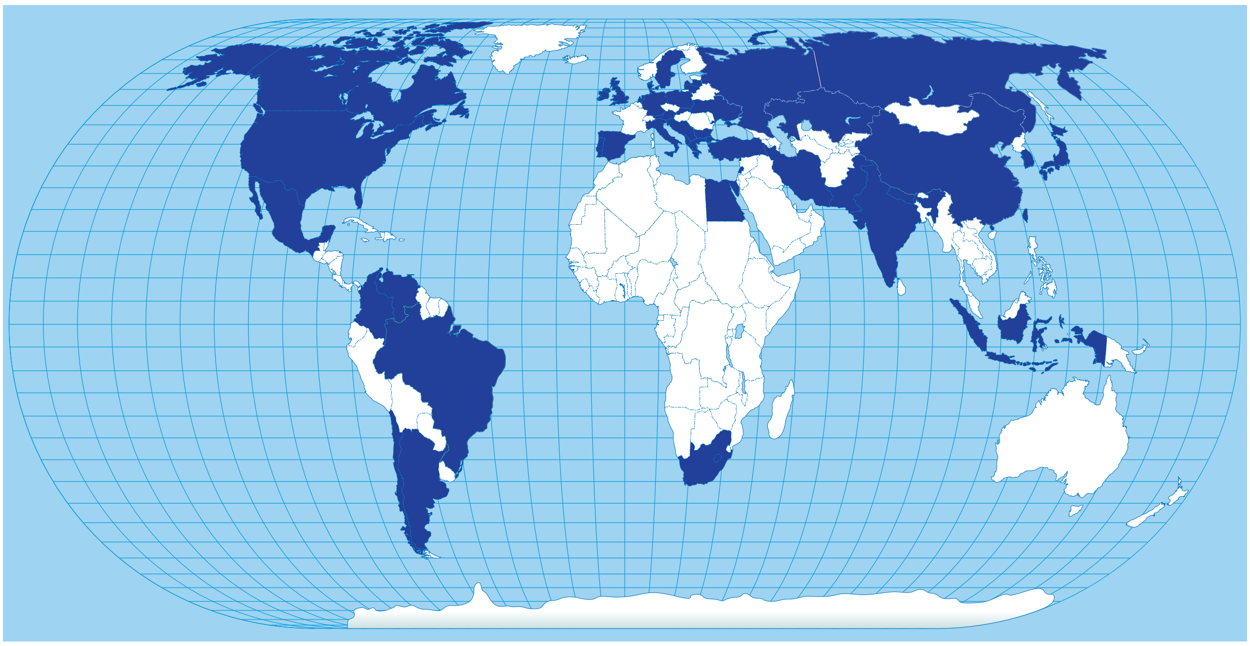
MPIA is one of the founders of the International Max Planck Research School »Astronomy and Cosmic Physics« at the University of Heidelberg, which provides an internationally competitive graduate program to German and international Students.

HAT-South

This collaboration between MPIA, Princeton University, Australian National University, Pontificia Universidad Catolica de Chile utilizes a network of six identical, fully automated wide-field telescopes on the Southern hemisphere to search for transiting exoplanets. The telescopes are located in Namibia, Australia and Chile.

Additional initiatives with active MPIA involvement are the technological collaboration Frontiers of Interferometry in Germany FrInGe, the Opticon network for institutes involved in planning and building optical and infrared instruments and telescopes, the international consortium Chemistry in Disks (CID) focusing on the chemistry and physics of protoplanetary disks, the strategic search campaign SEEDS looking for exoplanets and their disks with the Subaru Telescope, and the exoplanet search LEECH at the Large Binocular Telescope.

Fig. II.3.1: Countries of origin for the IMPRS-HD students (current fellows and alumni).



Credit: MPIA Graphic Department

Black Hole Powers »Cosmic Flashlight« Illuminating the Cosmic Web

Cosmologists believe that matter in intergalactic space is distributed in a vast network of interconnected filamentary structures known as the cosmic web. The vast majority of atoms in the Universe reside in this web as primordial hydrogen, vestigial matter left over from the Big Bang. Researchers from the University of California at Santa Cruz and the Max Planck Institute for Astronomy have captured an image of the cosmic web for the first time: they exploited the intense radiation generated by a supermassive black hole, which, like a flashlight, illuminates the cosmic web, revealing its structure.

Supercomputer simulations predict that matter in the Universe is distributed in a network of filaments known as the »cosmic web«, where the vast majority of atoms reside as diffuse hydrogen gas. In this picture, galaxies like our own Milky Way formed at the nodes of this network, where cool dense gas, the fuel for star formation, funnels in along the intersecting filaments. But direct tests of this model were previously lacking, because even at the densest nodes, cosmic web gas is so rarefied that it emits very little light, making it impossible to image even with the largest telescopes in the world.

Now astronomers have obtained the first direct images of a portion of the cosmic web, by exploiting the fact that a luminous object known as a quasar can act like a natural »cosmic flashlight«. Quasars constitute a brief phase in the galactic life-cycle. Powered by the infall of matter onto a galaxy's central supermassive black hole, they shine as the most luminous objects in the Universe. Because the galaxies hosting quasars should also reside at dense nodes of the web, the quasar can illuminate nearby cosmic web gas, revealing its structure.

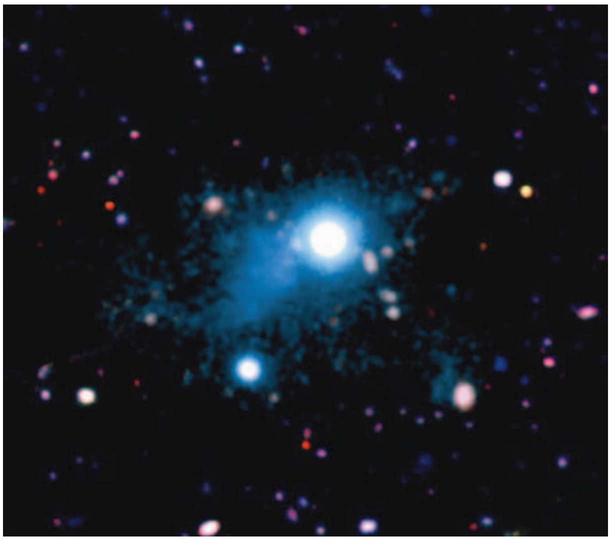
Under the quasar-flashlight's intense glare, the gas emits light via the same mechanism at work in an ordinary fluorescent lamp, namely because it is being constantly bombarded with energy. In the case of ordinary lamps this energy is provided by an electrical current, whereas the cosmic web fluorescence is powered by energy from the quasar radiation: Similar to the beam of a flashlight, the quasar shines directly onto the cosmic web, where its intense radiation makes some of the gas fluoresce.

The astronomers specifically targeted Lyman alpha emissions from this fluorescing gas with the Keck I telescope, a segmented 10 meter mirror telescope on top of Mauna Kea in Hawaii. Lyman alpha is one of the fundamental transitions of the hydrogen atom, namely that of an electron jumping from the lowest excited state (n=2) back to the ground state (n=1), resulting in an emission of ultraviolet photon at a very specific frequency or wavelength.

The objects observed in this case are very far away – so far away, in fact, that their light takes more than 10 billion years to reach earth. At such distances, the fact that the universe is expanding over time plays a key role: it induces what is known as a cosmological redshift, which means that light from such objects reaches us at substantially longer wavelengths than those at which it was emitted. Beyond a certain distance, Lyman alpha lines get shifted from the ultraviolet region of the spectrum into the visible part of the spectrum – and that is indeed the case for the observations discussed here.

The observations employed a custom-made narrow-band filter centered at about 400nm, which only transmits Lyman alpha photons which are redshifted to about three times its »rest-frame« wavelength; all other light is conveniently blocked out, allowing for very sensitive observations of Lyman alpha emission for ob-

Fig. II.4.1: The observed portion of the cosmic web (colored cyan) with a size of about 2 million light-years, which was discovered in the vicinity of the quasar UM 287 (at the center of the image). The gas is glowing thanks to the same effect that powers fluorescent lamps. This is the first extended image of part of the large-scale cosmic web of gas, which is thought to play a key role in supplying galaxies with the raw material to form new stars.



Credit: S. Cantalupo et al.

jects at a distance of about 10 billion light-years ($z = 2$). Using this filter, the researchers were able to capture an image of the fluorescently glowing cosmic web.

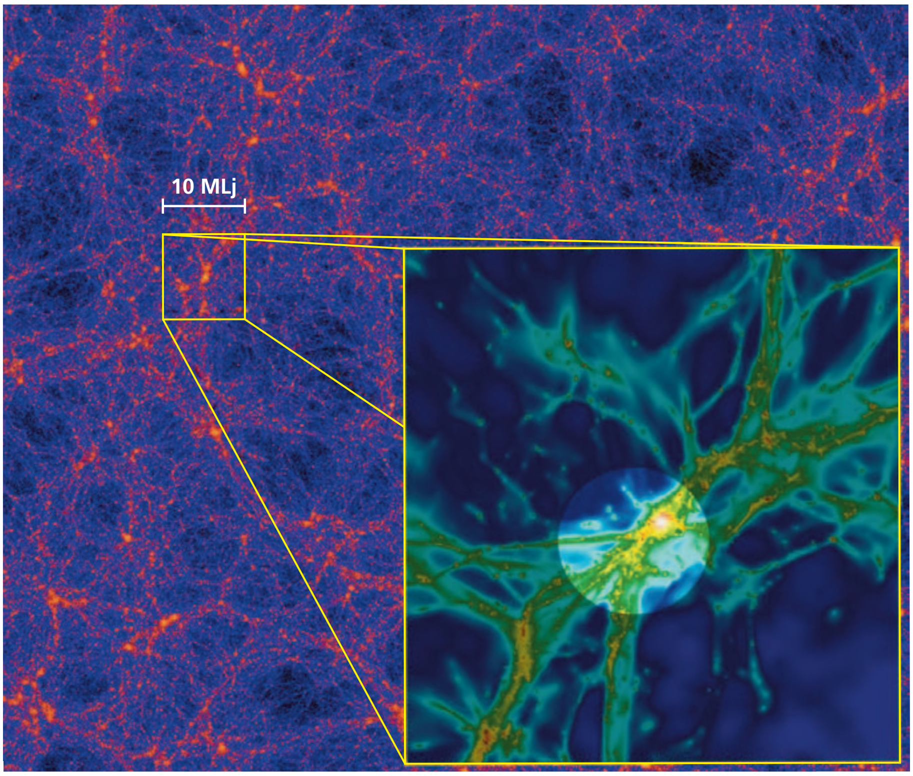
This is the first time astronomers have been able to obtain an image of gas in the cosmic web. Previously this gas was studied in absorption against background sources (cf. section II.8 in the 2013 edition of the MPIA annual report). These studies relied on chance alignments in which the light from a distant quasar would intersect part of the cosmic web on its way to earth. Absorption of some of the quasar radiation by the cosmic web gas would yield information about some properties of the gas. However, this method is limited by the paucity of bright quasars in the sky and the fact that the information obtained only applies to the gas directly along the line of sight – an inherently one-dimensional signal that cannot reveal the three-dimensional morphology of the cosmic web. Thus, the use of absorptions along the line of sights of bright quasars could never reveal the spatial structure of the net of filaments (cf. however section II.11 in this report for a potent alternative method). The new image, in contrast, clearly shows a piece of the cosmic web measuring roughly 2 million light-years across.

Images of this kind provide information about the size, morphology, clumpiness, as well as the total amount of gas in at least one region of the cosmic web. This information, in turn, is crucial input if you want to understand how galaxies evolve. In order to form new stars, galaxies need raw material, namely cool gas. Once you know the fuel supply of a galaxy – of which cold gas accreted from the cosmic web is a key ingredient – you can hope to understand why it is forming stars at a specific rate.

Concretely, observations like these can be used to test supercomputer models that simulate the formation of cosmic structures from the Big Bang to the present. Indeed, the new discovery provides evidence that key elements might be missing from current simulations. The amount of cool gas inferred from the image of the cosmic web appears to be substantially larger than predicted, and the observations also give a clue whence the discrepancy could arise: They suggest that a large amount of gas in the cosmic web is present in small, dense clumps. Such small clumps are not part of the current models of galaxy evolution – but they probably should be!

While, when it comes to small clumps, the ball is clearly in the court of the astronomers simulating galaxy evolution, further progress is to be expected on the observational

Fig. II.4.2: Computer simulations indicate the existence of a cosmic web of gas filaments on length scales of millions of light-years and above. The simulation in the background of this image shows the distribution not of gas, but of dark matter, which does not emit any light at all (Bolshoi simulation by Anatoly Klypin and Joel Primack). This dark matter forms the backbone of the cosmic gas web. The inset is a zoomed-in, high-resolution image of a smaller part of the cosmic web, 10 million light-years across, from a simulation that includes gas as well as dark matter (simulation: S. Cantalupo). The intense radiation from a quasar can, like a flashlight, illuminate part of the surrounding cosmic web (highlighted in the image) and make a filament of gas glow, as was observed in the case of quasar UM287.



Credit: A. Klypin / J. Primack and S. Cantalupo

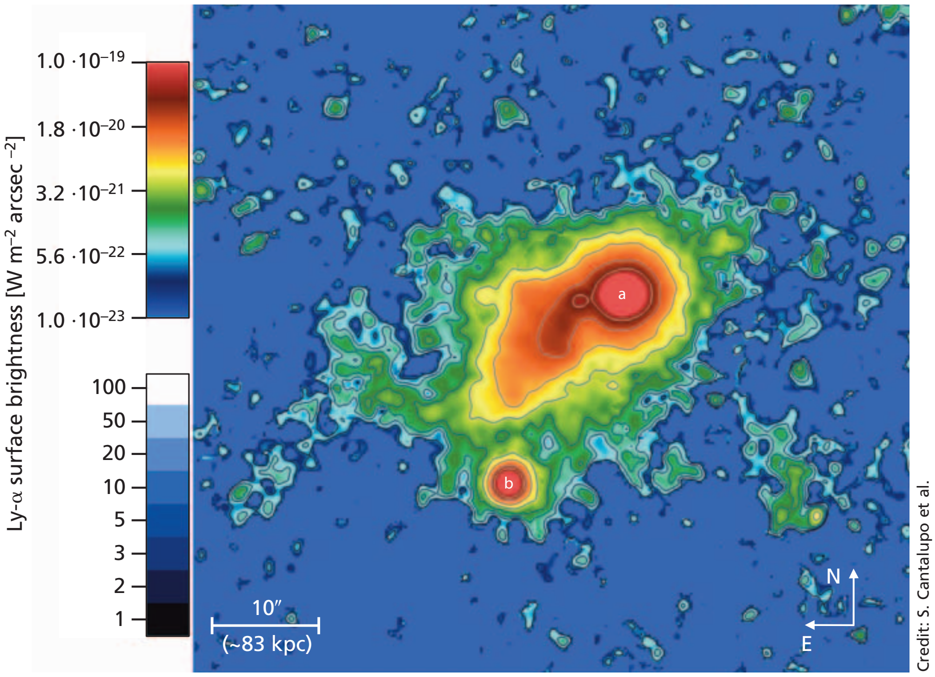


Fig. II.4.3: Lyman-α image of the UM287 nebula. To obtain this image, the astronomers took the narrow-band image and subtracted the background contributions (as estimated from images taken in a broader range of wavelengths). The label a indicates the location of UM287. The color map indicates the surface brightness of the Lyman-α radiation; the contours indicate the signal-to-noise (roughly how unambiguously Lyman-α radiation in that particular region was detected). The extended region emitting Lyman-α radiation appears under an angle of 55 arc seonds, corresponding to an actual size of about 1.5 million light-years (460 kpc). The object marked as b is an optically faint quasar at roughly the same distance (same redshift) as UM287. The two quasars do not appear to be connected directly by any gas filaments.

front as well. The observations reported here were obtained as part of a 200 hour observing program at the Keck telescope and the Gemini South telescope (Chile) as part of the FLASHLIGHT survey. At the moment of writing, the observations and data reduction of this survey are completed, with a total of 24 additional quasars imaged with the same method described earlier. Specifically, 17 quasars were observed using the Gemini South telescope in Chile, while 7 quasars were observed at Keck. The same team of researchers will present the overall analysis during 2015, and are currently involved in a new survey targeting quasars with the MUSE instrument on the Very Large Telescope in Chile (80 hours awarded).

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with

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(University of California at Santa Cruz)

S. Cantalupo et al. 2014: »A cosmic web filament revealed in Lyman-alpha emission around a luminous high-redshift quasar« in Nature 506, pp. 63-66. DOI: 10.1038/nature12898

II.5 Scientific Highlight

First Surface Map of a Brown Dwarf Shows Extraterrestrial Weather Patterns

Astronomers have presented the first detailed study of the atmospheric features – the extraterrestrial weather patterns – of a brown dwarf (an intermediate object between planet and star). The results include the first surface map of a brown dwarf and measurements at different wavelengths probing its atmosphere at different depths. They mark the beginning of an era in which astronomers will be able to compare models for cloud formation on brown dwarfs – and, eventually, on giant gas planets in distant star systems – with observations.

A brown dwarf is a peculiar object: more massive than a planet, but with insufficient mass for the nuclear fusion that powers stars to ignite in the object's core. The discovery of a brown dwarf system a mere 6.5 light-years away from the sun (only two star systems are closer than that!), announced in March 2013, presented astronomers with the opportunity to study such objects in more detail than ever before. The discovery was made by Kevin Luhman Pennsylvania State University, using data from NASA's infrared observatory WISE. Their catalogue numbers are WISE J104915.57-531906.1 A and B, with A and B the conventional way of denoting double star (or brown dwarf) components. As Luhman had previously discovered 15 other binary systems, the new system has also been called Luhman 16, and the two objects Luhman 16A and 16B.

This is the closest star system found in nearly a century. It is only slightly more distant than the second-closest star, Barnard's star, discovered in 1916. Due to its close proximity to earth, the Luhman 16 system presents astronomers with the best opportunity yet to study brown dwarfs in detail. Two studies of these new objects were led by researchers from the Max Planck Institute for Astronomy – and promise the start of a new era of research on brown dwarfs.

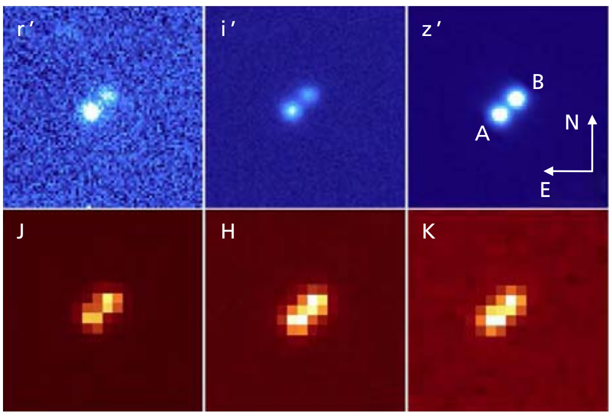
The first study, led by Ian Crossfield of the Max Planck Institute for Astronomy, presents nothing less than a surface map of Luhman 16B. Crossfield's team used a method known as Doppler imaging, which has never before been used with this type of objects.

With current technology, it is not possible to produce surface maps of this brown dwarf (or other distant stars and brown dwarfs) in the same way that we would, say, map the cloud bands of Jupiter, namely by directly taking images that show all the details. Instead, Doppler imaging makes use of the fact that light from a rotating star is slightly shifted in frequency as the star rotates. From the systematic shifts, an approximate map of the stellar surface can be reconstructed.

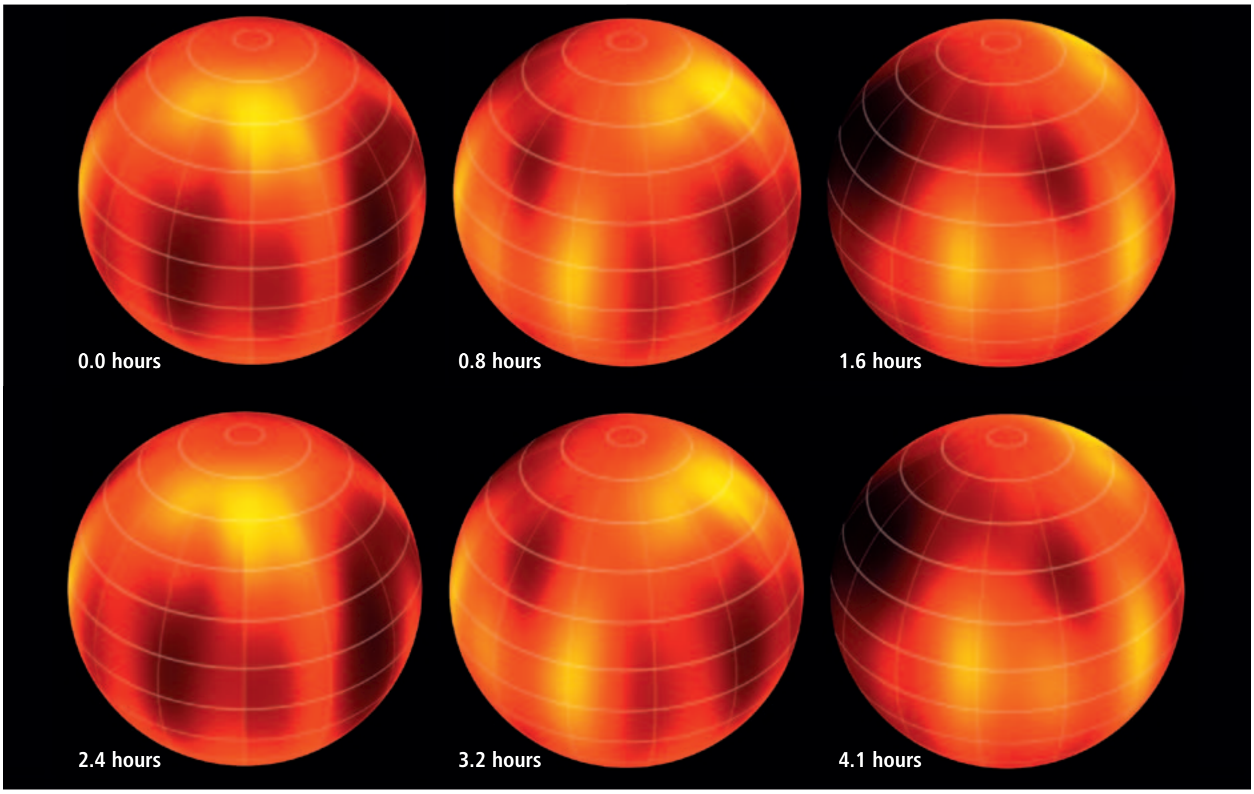
For a rough picture of how this happens, it is useful to imagine an observer hovering high above the earth's equator, watching the globe spin beneath. As an object sitting on the equator comes into view, it will first move toward the observer while crossing the horizon and coming into sight; as it passes directly beneath, its distance from the observer will change very slowly, while as it passes across the horizon out of sight, it will move away from the observer at speed. An object placed at higher latitudes (that is, shifted towards one of the poles) will follow a similar pattern, but at overall lower speeds. An object situated at one of the poles will not move towards or away from the observer at all as the earth rotates.

For a brown dwarf and an observer far away on earth the situation is somewhat analogous. Whenever a bright surface spot rotates into sight, the way it moves directly towards or away from the observer will depend on latitude, while the timing of when it rotates into and out of sight defines its longitude. And while astronomers cannot follow the spot's travels directly, they can measure the so-called Doppler shift: Light will change its wavelength very slightly depending on whether, and how fast, the emitting object is moving towards or away from the observer. In this way, brighter spots create a complex pattern of superimposed light of different wavelengths,

Fig. II.5.1: Single frame optical and near-IR images in six different near-infrared filters (r'i'z' JHK), showing Luhmann 16A and 16B. The two components are separated by 1.″5, less than half a thousandth of a degree.



Credit: Beth Biller

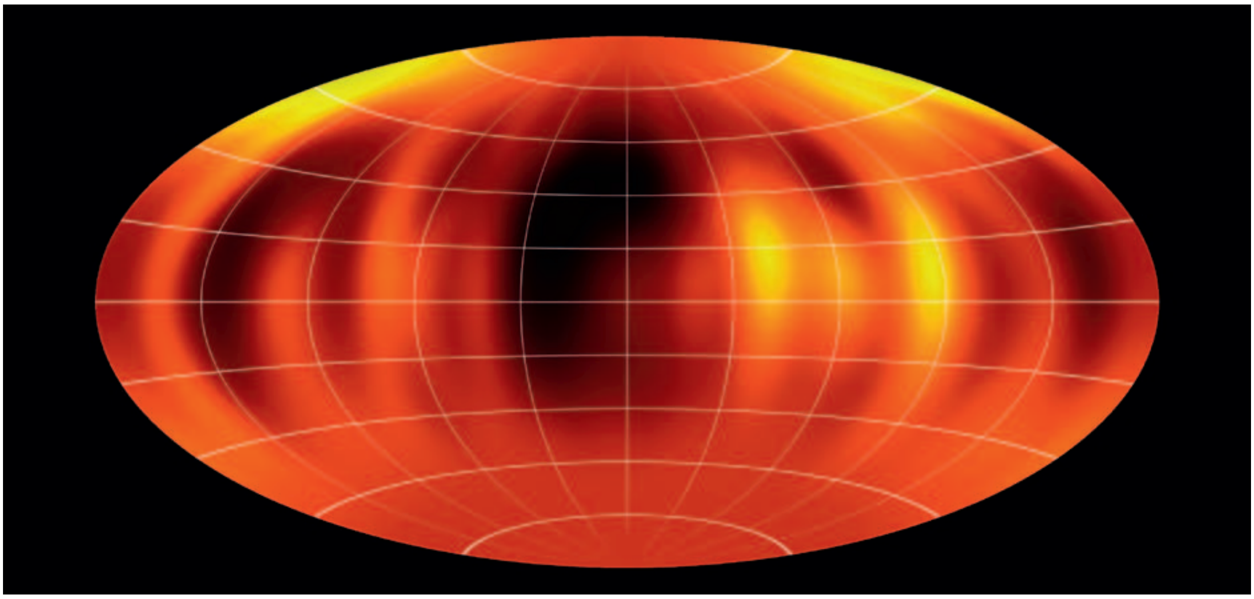


Credit: ESO / I. Crossfield

Fig. II.5.2: Surface map of brown dwarf Luhman 16B, which clearly depicts a bright near-polar region (as seen in the panels on the upper right) and a darker area closer to the equator (cf. the panels on the lower left) consistent with large-scale cloud inhomogeneities. The lightest and darkest regions shown correspond to brightness variations of roughly ±10%. The time index of each projection is indicated.

shifting over time. Crossfield and his colleagues recorded this pattern, splitting Luhman 16B's light into a rainbow of different wavelengths, with the spectrograph CRIRES, which is installed on one of the 8 meter Very Large Telescopes (VLT) at ESO's Paranal observatory in Chile, in May 2013.

Fig. II.5.3: The complete surface map of Luhman 16B recreated from VLT observations, in a Aitoff projection similar to that of global maps of the earth.



Credit: ESO / I. Crossfield

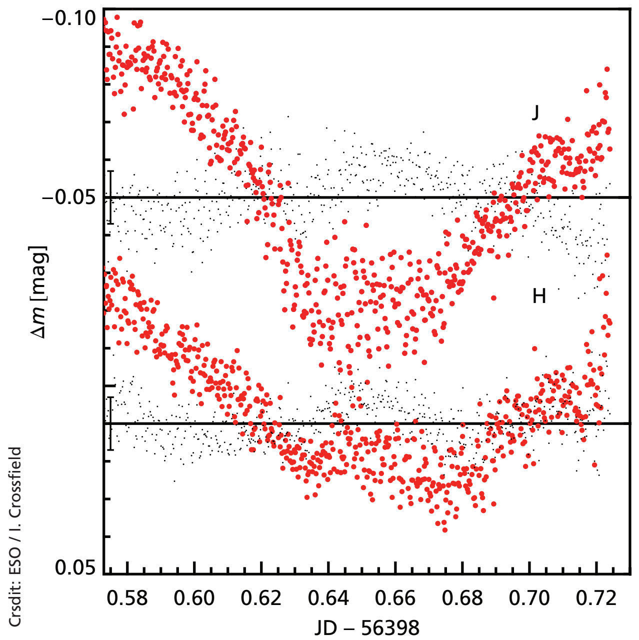


Fig. II.5.4: Light curve showing the combined light from Luhman 16A and 16B, from observations on 16 April 2013. The estimated error bars are plotted at the beginning of each light curve, and example residual reference light-curves (for a reference star with a high signal to noise ratio) are plotted as small dots. The differences between the light curves at various frequencies indicate the complex structure of the observations, with different layers of brown dwarf atmosphere dominating different filter bands.

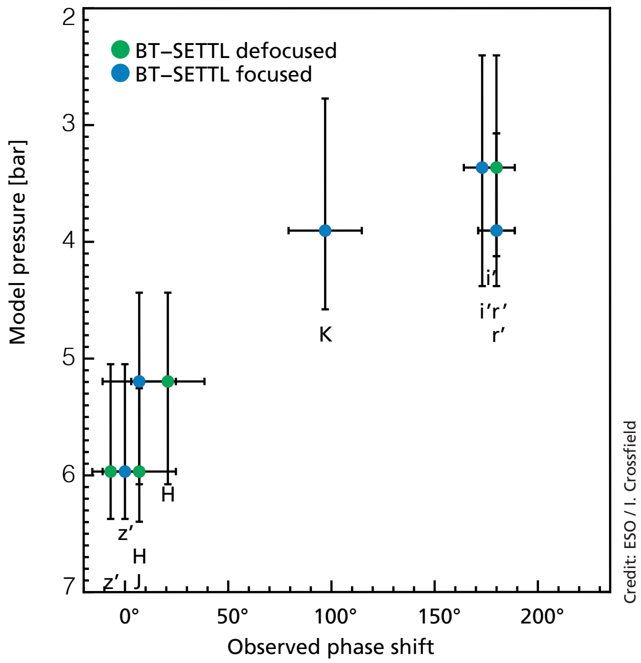


Fig. II.5.5: Observed phase shift vs. average model atmosphere pressure probed for both the defocused and focused observations, using the BT-Settl atmospheric model. Biller et al. found a correlation of phase shift with model pressures, with flux from the higher layers of the atmosphere phase shifted relative to the z' band extremum. The filters z', J and H probe deepest into the atmosphere (with pressures between 5 and 6 bar), while r' and i' probe higher layers (pressures between 3 and 4 bar). The correlation between atmospheric depth and phase offset is similar to that previously seen in the cooler T6.5 brown dwarf 2MASS J22282889-431026 by Buenzli et al. (2012). The phase shifts indicate that the vertical and horizontal structure of the atmosphere must explicitly be taken into account.

Combining the Doppler shift patterns hinting at latitude with timing of observations, which exposes different longitudes, it is possible to reconstruct the brown dwarf's surface pattern. The reconstruction involves some ambiguity and uncertainty, but the result shown here is the most probably surface structure deduced from the many Doppler measurements made by Crossfield et al.

While previous observations had inferred that brown dwarfs should have mottled surfaces, the images are the first to show these surface features directly. Presumably, they show a patchy cloud cover, somewhat similar to that on the surface of Jupiter – a very rough version of satellite weather maps on our home planet. For humans, however, Brown Dwarf weather will always be rated as »extremely inclement«. At temperatures of about 1100 C, the clouds are believed to be made of minute droplets of molten iron and various minerals, floating in an atmosphere that is mostly hydrogen.

The second study, led by Beth Biller, literally goes to greater depths. As brighter and darker clouds are moved into view and removed again by a brown dwarf's rotation, its brightness will change. By simultaneously observing brightness variations at different wavelengths, Biller and her colleagues were able to reconstruct what happens in different layers of the atmosphere for both Luhman 16A and 16B.

Their brightness measurements used the astronomical camera GROND at the ESO/MPG 2.2-m-telescope at La Silla observatory in Chile in April 2013. GROND was built by the high-energy group of the Max Planck Institute for Extraterrestrial Physics in Garching in collaboration with the Tautenburg State Observatory and ESO, and it can take images simultaneously in seven different wavelength regions (filter bands).

Emission in these seven different wavelength regions is directly correlated with the temperature of the emitting gas, and most likely the different wavelengths represent layers at different depths of the brown dwarf atmosphere. The observations thus allow the researchers to probe different depths of the atmosphere, revealing a complex pattern: The cloud structure of the brown dwarf varies quite strongly as a function of atmospheric depth and cannot be explained with a single layer of clouds.

Taken together, the new results – both the first map of a brown dwarf surface, and the first monitoring of brown dwarf brightness variability in more than two wavelength ranges (filter bands) – usher in a new phase of brown dwarf research in which observers are able to provide details both of surface structure and of the different atmospheric layers. The results show distinguishable cloud features, and also that this brown dwarf must have multiple layers of patchy clouds and/or temperature variations to produce the observed variability. This is the first detection of this kind of complex, evolving weather patterns on a brown dwarf, that involves a surface map, and also the first that involves monitoring at such a variety of wavelengths.

Theorists are now called upon to provide better and more detailed models for the atmospheric structure of brown dwarfs – which, in concert with new observational data similar to the one described here, should lead to a much more detailed understanding of these borderline objects.

Given the development of new telescopes, the results presented here are likely just the beginning. With telescopes of the next generations, in particular the European Extremely Large Telescope (E-ELT) with its 39 meter mirror, astronomers can expect to see surface maps of more distant Brown Dwarfs – and for Luhman 16B, to map even finer details, watching how cloud patterns form, evolve, and dissipate. Eventually, exo-meteorologists might be able to predict whether a hypothetical visitor to Luhman 16B could expect clear or cloudy skies.

Beyond that, the new results represent significant progress towards a much more ambitious goal: understanding weather patterns in other planetary systems. The next step is likely to involve the SPHERE instrument, an instrument which has commenced operations at ESO's Very Large Telescope at Paranal Observatory in mid-2014 (cf. section III.3 in this report). SPHERE, which was developed by a consortium headed by Jean-Luc Beuzit (PI) of the Laboratoire d'Astrophysique de l'Observatoire de Grenoble (France) and Markus Feldt (Co-PI) of the Max Planck Institute for Astronomy in Heidelberg, should be able to perform similar measurements for giant exoplanets. Theorists have also already proposed various ways that weather patterns and surface features could be described on small, cool, Earth-like planets, but the observatories needed for that still lie many decades in the future.

Ian Crossfield (now at the University of Arizona), Beth Biller (now at the University of Edinburgh), Joshua Schlieder, Niall Deacon, Mickaël Bonnefoy, Esther Buenzli, Thomas Henning, Wolfgang Brandner, Bertrand Goldman, Taisiya Kopytova, Luigi Mancini, Simona Ciceri, and Coryn A.L. Bailer-Jones

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Derek Homeier and France Allard (both CRAL-ENS, Lyon), John Southworth (Astrophysics Group, Keele University), Bernd Freytag (Department of Physics and Astronomy, Uppsala Universitet), and Jochen Greiner (Max-Planck Institute für extraterrestrische Physik, Garching)

I. J. M. Crossfield et al., »Mapping Patchy Clouds on a Nearby Brown Dwarf« in Nature 505 (2014), S. 654-656. DOI: 10.1038/nature12955

B. A. Biller et al., »Weather on the Nearest Brown Dwarfs: Resolved Simultaneous Multi-Wavelength Variability Monitoring of WISE J104915.57-531906.1AB« in Astrophysical Journal Letters, Bd. 778, Artikelnummer L10. DOI: 10.1088/2041-8205/778/1/L10

II.6 Scientific Highlight

Where Little Galaxies Come from: Cosmic Collisions between Dwarfs

Galaxies grow by attracting and ingesting smaller galaxies or by merging with galaxies of comparable size. Recently, a team of astronomers, including Glenn van de Ven from the Max Planck Institute of Astronomy, have identified the smallest example of a remnant of such a galactic merger: the dwarf spheroidal galaxy Andromeda II (AndII), a satellite of the well-known Andromeda galaxy. From the motion of stars within this galaxy, the researchers identified two distinct groups of stars: what appears to be stars of the original dwarf galaxy, and stars from another dwarf galaxy that merged with AndII.

In the current picture of galaxy evolution, mergers and acquisitions are the key to galactic growth: smaller galaxies grow large by swallowing other small galaxies, notably dwarf galaxies. Our own Milky Way, a disk galaxy, has reached its present size in this way. The huge elliptical galaxies are formed in the merger of two (or more) large progenitor galaxies.

In 2014, astronomers including MPIA's Glenn van de Ven, have identified the smallest known result of such a merger – the first step in a development that over the course of billions of years can lead to galaxies with hundreds of billions of solar masses. The discovery started out as an anomaly: A group of astronomers in the USA, led by Marla Geha, had used the DEIMOS spectrograph at the Keck telescopes to measure radial velocities for more than 700 stars in AndII, a small galaxy in the constellation Andromeda (Ho, Geha, Muñoz et al. 2012). They had found

Fig. II.6.1: Artist's impression of the merger between two smaller dwarf galaxies; the result was the dwarf galaxy Andromeda II.

Credit: N. C. Amorisco & M. Høst (Niels Bohr Institute) and ESO / Digitized Sky Survey 2

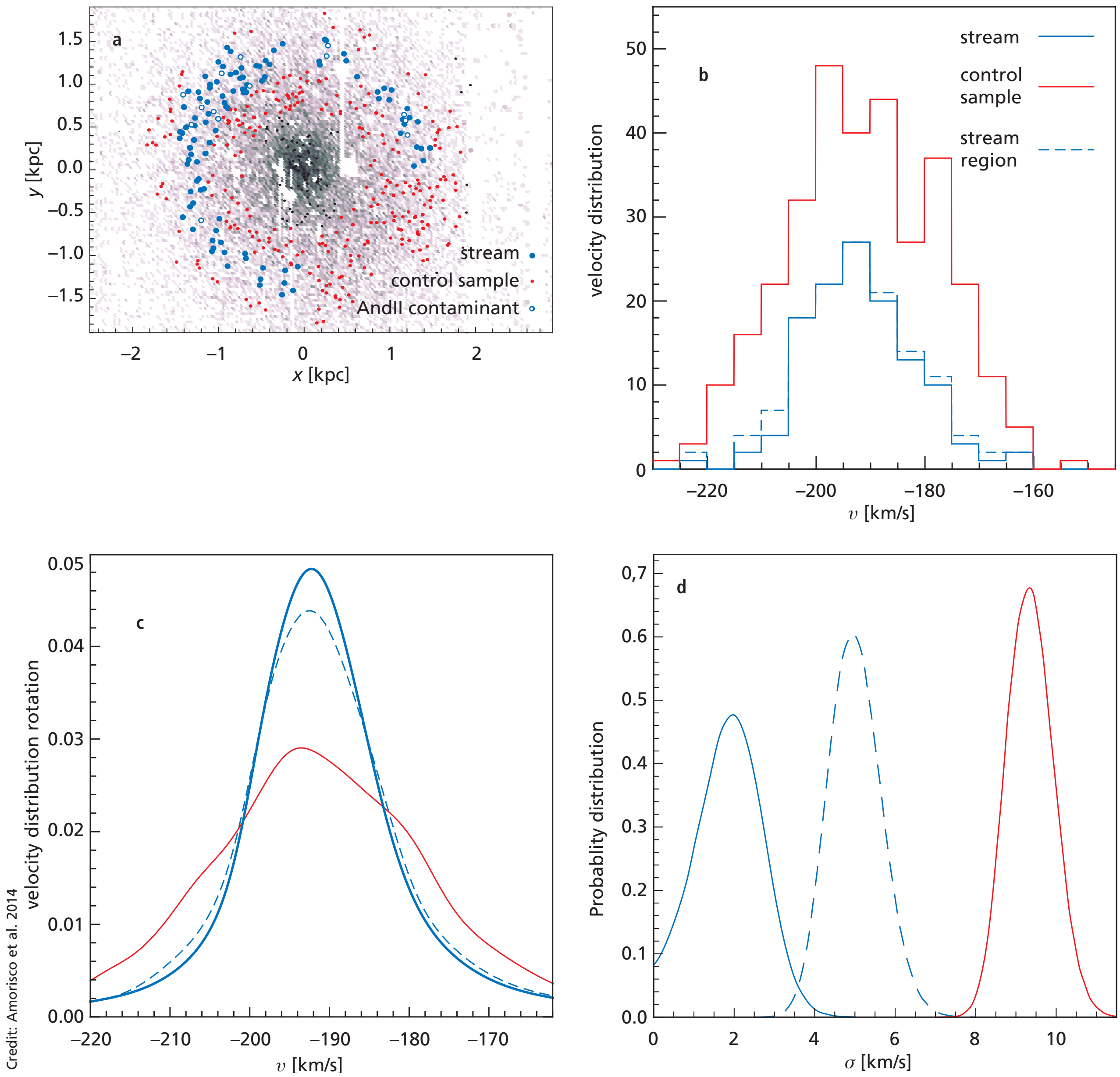


Fig. II.6.2: Part (a) shows the image of the dwarf galaxy Andromeda II in which the two distinct groups of stars were identified. The connected stream-like region between 2300 and 6200 light-years (0.7 kpc – 1.9 kpc) from the center contains 134 stars, shown here as blue points. For comparison, 319 stars outside that region were selected as a control sample (red points). On closer examination, 14 stars in the stream-like region were identified as not belonging to the stream, after all; those are shown as open blue dots. In parts (b)–(d), different properties of the distinct groups of stars are shown; in all these plots, the red line indicates the control sample, the dashed blue line all stars in the stream-like region and the solid blue line the stream-like stars excluding the contaminant stars. Part (b) shows the velocities along the line of sight (that is, directly towards or away from the observer) for the different kinds of stars. Once the mean motion of the stars of the galaxy is subtracted and the velocity distribution normalized, the result is figure (c). From the line-of-sight velocities one can deduce the speed distribution within the different groups of stars; the result (in the shape of the velocity dispersion) is shown in part (d).

that the overall rotation was not only much faster than in other dwarf spheroidal galaxies, but also rather unusual in orientation: Usually, galaxies spin like a wheel along its axis. In comparison, this galaxy tumbled head over heel.

With this anomaly in mind, the observers kindly provided their data to a group of researchers well known for their experience in modeling stellar motion in galaxies: MPIA's Glenn van de Ven, Wyn Evans of Cambridge University, and Nicola Amorisco of the University of Copenhagen. Amorisco, Evans, and van de Ven carefully re-analyzed stellar motion in AndII, using tools they had developed in their earlier research.

The re-analysis focuses on the radial velocities of more than 700 individual stars in the field of Andromeda II.

Among these stars, there is a subgroup that exhibits a more ordered kind of motion (»kinematically colder«) consistent with a stellar stream within that galaxy: The remnant of a smaller galaxy that has merged with the original Andromeda II. The overall properties of the stellar motion, and in particular the small overall degree of disordered motion of the stars among themselves, are strong evidence that this was indeed a merger event, not, say, a fly-by in which Andromeda II was gravitationally disturbed by another galaxy. AndII seems to be the remnant of a merger of two even smaller dwarf galaxies. The unusual rotation is then a consequence of the smaller dwarf galaxy orbiting the larger one before being absorbed. That is why the stars fall into two distinct groups: Those that were part of the original dwarf galaxy, and those that were accreted from an even smaller dwarf galaxy in a galaxy merger. The latter stars form a stellar stream that is wrapped around the inner regions of AndII like a belt.

For the merger time, only a lower limit can be estimated: In order to reach the state actually observed, the merger must have taken place more than 3 billion years ago. There is no indication, however, whether this happened 3 billion years after the Big Bang, or 3 billion years before the present.

Interestingly, already in 2007 in a study of the distribution of stars in AndII, astronomers had speculated about a possible relic of an earlier merger: an unusual group of very old stars within the galaxy. The discovery of the stellar stream puts this speculation onto much firmer ground.

Such stellar streams, the characteristic remnant of a smaller galaxy captured by a larger one, have been found around our own Milky Way galaxy and other larger galaxies – but never for a galaxy with a mass of less than a billion suns. AndII has a much lower mass, corresponding to a mere 10 million Suns. In other words: Up until then, astronomers had only found traces of later stages of galaxy evolution – cases where at least one of the galaxies was already fairly massive, the result of many previous mergers and captures. This is the first example for a stellar stream in a very small galaxy – and thus the first examples for the first steps of galactic growth, with small dwarf galaxies swallowing even smaller dwarfs.

Amorisco, Evans, and van de Ven hope that the next discoveries of this kind might be just around the corner. Using their method, astronomers who have similar data for other dwarf galaxies should be able to look for traces of stellar streams – and possibly identify even less massive mergers. But even with this one example, it looks like the current model of galaxy evolution is right on the money when it comes to explaining where little galaxies come from.

Glenn van de Ven

with

Nicola Amorisco (University of Copenhagen)
and Wyn Evans (University of Cambridge)

N. C. Amorisco, N.W. Evans and G. Van de Ven: »Kinematic detection of a stellar stream in the galaxy Andromeda II« in Nature 507 (2014), pp. 335-337. DOI: 10.1038/nature12995

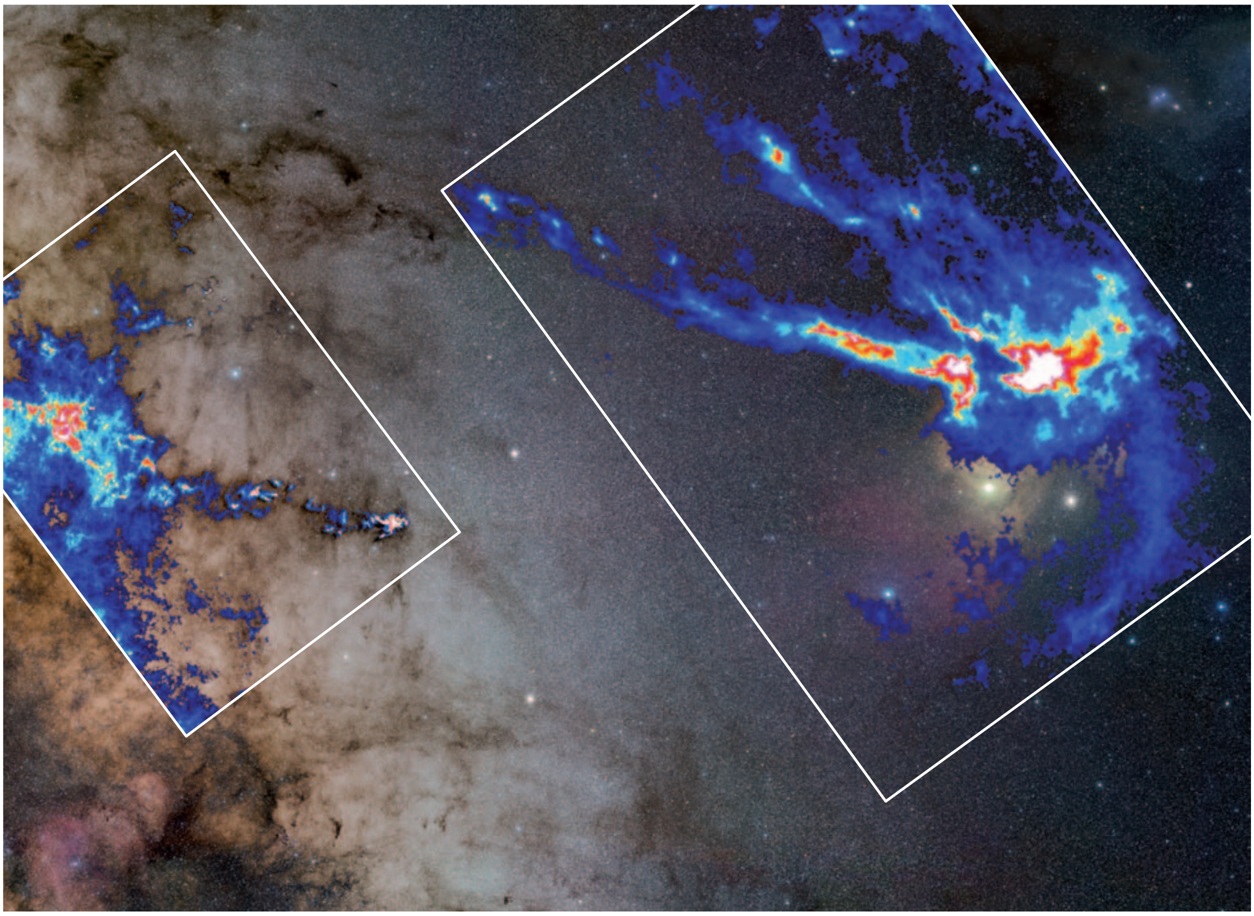
Finding the »Recipe for Star Formation«

Astronomers led by MPIA's Jouni Kainulainen have found a new way of predicting the rate at which a molecular cloud – a stellar nursery – will form new stars. Using a novel technique to reconstruct a cloud's three-dimensional structure, the astronomers were able to estimate how many new stars the cloud is likely to form. The newfound »recipe« allows for direct tests of current theories of star formation. It will also enable telescopes such as the Atacama Large Millimeter/submillimeter Array (ALMA) to estimate the star-formation activity in more distant molecular clouds, and thus to create a map of star births within our home galaxy.

Star formation is one of the fundamental processes in the universe – how stars form, and under what conditions, shapes the structure of entire galaxies. Stars form within giant clouds of interstellar gas and dust. As a sufficiently dense region within such a molecular cloud collapses under its own gravity, it contracts until the pressure and the temperature inside are high enough for nuclear fusion to set in, signaling the birth of a star.

Measuring star formation rates is extremely challenging, even throughout our home galaxy, the Milky Way. Only for nearby clouds, up to distances of about 1500 light-years, are such measurements fairly straight-

Fig. II.7.1: Two of the molecular clouds studied by Kainulainen and colleagues: The Pipe Nebula (left) and the Rho Ophiuchi cloud (right) in the Milky Way. In the background, an ordinary image of the Milky Way; each inset map shows to what extent the light of background stars is dimmed as it passes through the cloud in question. These maps form the basis of the three-dimensional reconstruction of cloud structure from which the astronomers derived their »recipe for star formation«.



Credit: Background: ESO/S. Guisard (www.eso.org/~sguisard) Column-density maps: J. Kainulainen, MPIA forward: You simply count the young stars within that cloud. For more distant clouds, where it is impossible to discern individual stars, this technique fails, and star formation rates have remained uncertain.

Recently three astronomers, Jouni Kainulainen and Thomas Henning from the Max Planck Institute for Astronomy in Germany, and Christoph Federrath from Monash University in Australia, have found an alternative way of determining star formation rates: a »recipe for star formation«, which links direct astronomical observations of the structure of a giant gas cloud to its star formation activity.

The astronomers arrived at their result by modelling the three-dimensional structure of individual clouds in a simplified way, similar to the way medical X-ray imaging works: As the light from distant stars passes through a molecular cloud on its way to earth, some of it is absorbed and scattered. The resulting dimming of the light of tens of thousands of different stars can be plotted as a map, which shows how much matter the light has traversed in each part of the cloud (»column density«). To this dimming map, Kainulainen and his colleagues fitted a simple three-dimensional structure made up of simple shapes: longish or less longish cigar-shaped regions of space (»prolate ellipsoids«). As a simplification, these cigars are assumed to be oriented at right angles to the line of sight. In a comparison with computer simulations, the astronomers showed that, even with this simplification, the reconstruction yields a good estimate for the three-dimensional structure – for a decomposition of the cloud into regions of different size and with different densities.

For nearby clouds, with distances up to 1000 light-years, Kainulainen and his colleagues compared their reconstruction and direct observations of how many new stars had recently formed in these clouds. Previously, observations of cloud structure had been disconnected from the theory of star formation in these clouds. Star formation models talked about densities. Observational astronomers produced two-dimensional emission maps (of light emitted by dust or molecules in those clouds) or absorption maps (of light from a distant star that is dimmed as it passes through the cloud) in the plane of the sky. The new reconstruction technique presented here brings observations and theory together much more directly than previous estimates, as it directly reconstructs a cloud's density structure from the available data.

In this way, the astronomers were able to identify a »critical density« of 5000 hydrogen molecules per cubic centimeter, and showed that only regions exceeding this critical density can collapse to form stars. Theories of star formation had long predicted the importance of such a critical density. But the new reconstruction technique is the first to allow astronomers to deduce the density structure of these clouds – and to confront star formation theories' claims about a critical density with observational data.

Fig. II.7.2: Probability density functions for the volume density of the star-forming molecular cloud Serpens South, based on a column density map derived from dust extinction mapping. As turbulence theory predicts, the distributions closely follow log-normal functions (solid lines). The dark blue region corresponds to star-forming gas, while lighter blue corresponds to the major structures enveloping the star-forming gas. Green corresponds to comparatively non-structured gas.

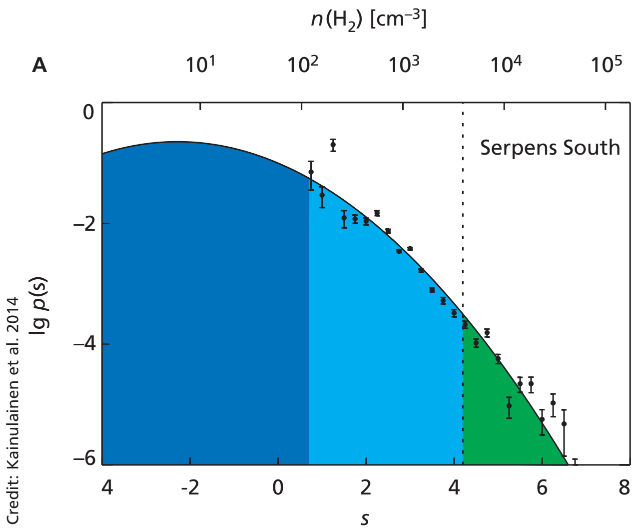
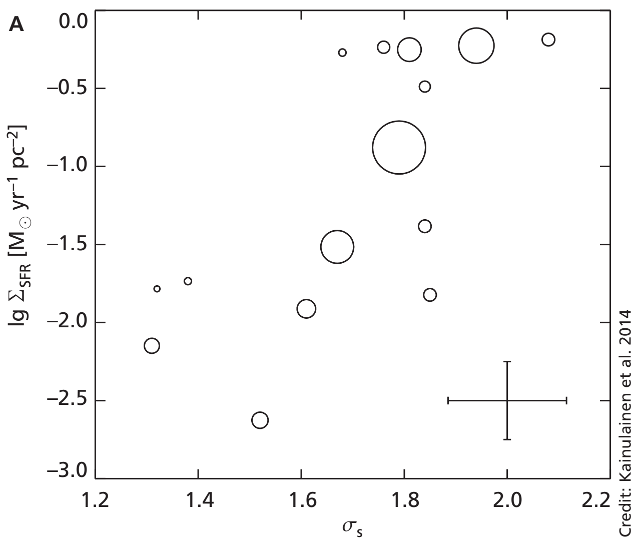


Fig. II.7.3: : Plotting the widths of the probability density functions for the volume density (s) against the star-formation rate surface densities (SFR) shows a correlation between the two. The sizes of the circles indicate cloud mass, which ranges from 700 to 36,000 solar masses. The error bars indicate statistical uncertainty at the 1σ level.



Credit: C. Federrath, Monash University

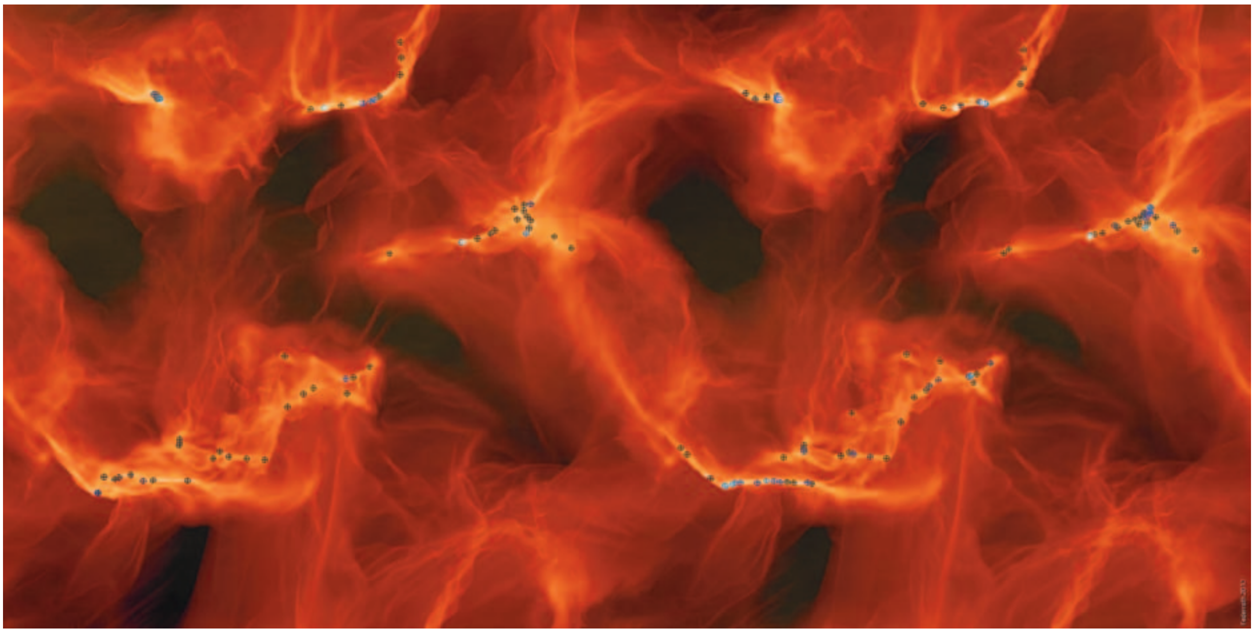


Fig. II.7.4: Computer simulation of star formation in a turbulent gas cloud. These and similar simulations were used by Kainulainen and his colleagues to test their method for reconstructing the three-dimensional structure of such clouds. Regions in which stars are forming are marked by small circles; brighter colors correspond to more massive stars.

On this basis, astronomers can now hope to tackle one of the great unanswered questions of astrophysics: If stars form within a cloud of a given mass, how many stars will form, and what will their masses be? With a way of answering that question, a lot of existing data about molecular clouds can now be put to new use - namely to estimating star formation rates in distant molecular clouds whose star formation activity cannot be deduced by other means. With the advent of the telescope array ALMA, much more precise data for more distant clouds will become available. ALMA is an array of 66 high-precision microwave antennas, spread over distances of up to 16 kilometers in the Chilean desert, and able to act as a single, high-resolution telescope. ALMA has just commenced operations, and can detect clouds of gas and dust with unprecedented sensitivity, and in more detail than ever before. ALMA examines these clouds not by observing the dimming of stars, but by receiving radiation from the dust contained within the clouds.

With the potent new tool linking cloud properties and the critical density, astronomers will be able determine star formation rates for more clouds than ever before, both within our own galaxy and in distant other galaxies.

Jouni Kainulainen and Thomas Henning

with

Christoph Federrath (Monash University)

Jouni Kainulainen, Christoph Federrath and Thomas Henning: »Unfolding the Laws of Star Formation: The Density Distribution of Molecular Clouds« in Science, Volume 344 (2014), pp. 183-185. DOI: 10.1126/science.1248724

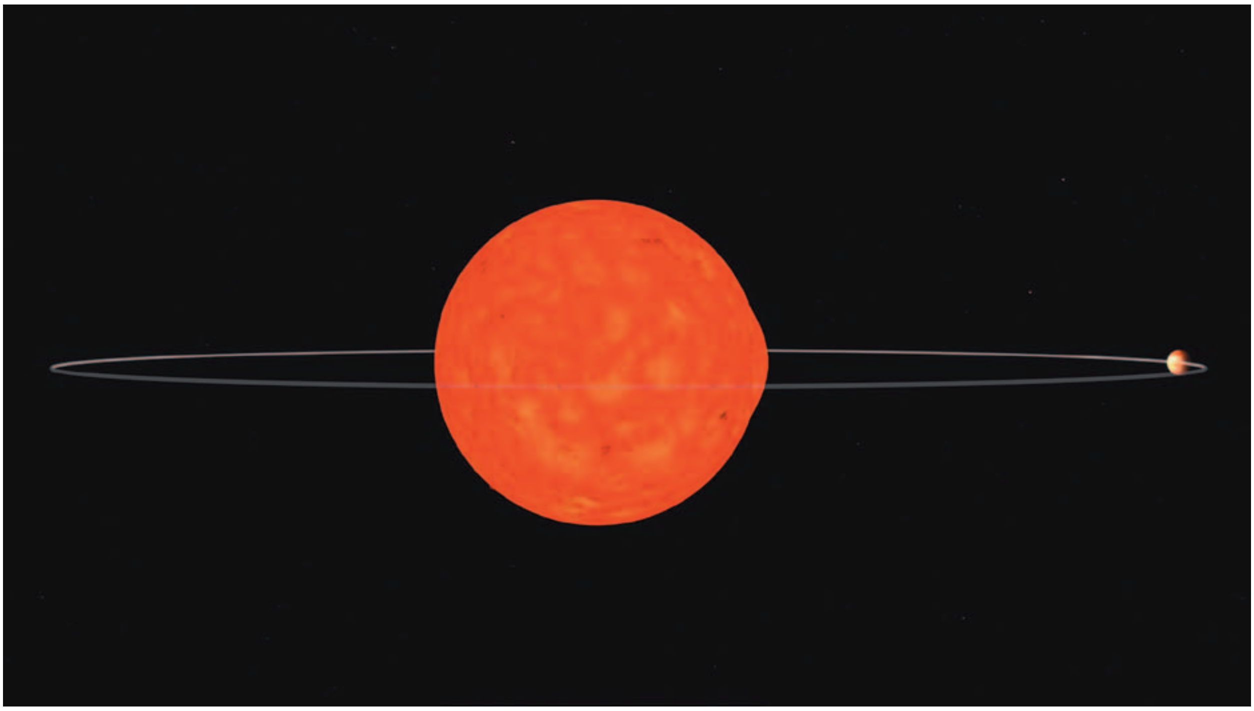
Doomed Planet Confirmed

Kepler-91b is doomed: In an estimated 55 million years it will be engulfed by its host star, a red giant. Recent studies, though, suggested a completely different type of doom, claiming there might not be such a thing as the planet Kepler-91b at all. Instead, according to those studies, what had been observed might instead be a fairly dim star. Now new observations with the CAFE spectrograph at Calar Alto observatory have settled the case: Kepler-91b is indeed a planet. The result also validates the method used for the original detection, an unusually detailed analysis of light received from the planet's host star.

When a group of astronomers including Amelia Bayo and Luigi Mancini of the Max Planck Institute for Astronomy announced the discovery of the planet Kepler-91b in December 2013, the main point of interest was the planet's imminent demise: The observations showed that an estimated 55 Million years from now – a mere blink of the eye compared to usual astronomical time scales – the planet would be engulfed by its parent star, a red giant. The same fate awaits the earth in about five billion years, when our sun will become a red giant star es well.

The astronomers, led by Jorge Lillo of the Center of Astrobiology (CAB) in Madrid, had employed an unusual method to detect Kepler-91b, making use of data from NASA's Kepler Space Telescope. They had concentrated on a planet candidate, designated KOI2133.01, that had not then be confirmed as a planet. From 2009 to 2013, the Kepler telescope monitored the brightness of 190,000 stars with unparalleled precision. A planet around one of those stars which occasionally passes directly between the star and an observer here on earth will cause periodic dips in the star's brightness. The difficult bit is deciding which dips in brightness indicate the presence of a presence, and which are caused by other phenomena, such as dark spots on the star's surface. Once the Kepler telescope has found a planet candidate, further observations or further analysis are necessary.

In most confirmed cases, the additional evidence is provided by spectroscopic observations, which reveal the periodic motion of the host star due to the planet's presence (»radial velocity method«); this has lead to the confirmation of almost a thousand planets. Recently,



Credit: David Cabezas Jimeno

Fig. II.8.1: Artist's impression of the planet Kepler-91b which will be swallowed by its host star shortly (astronomically speaking).

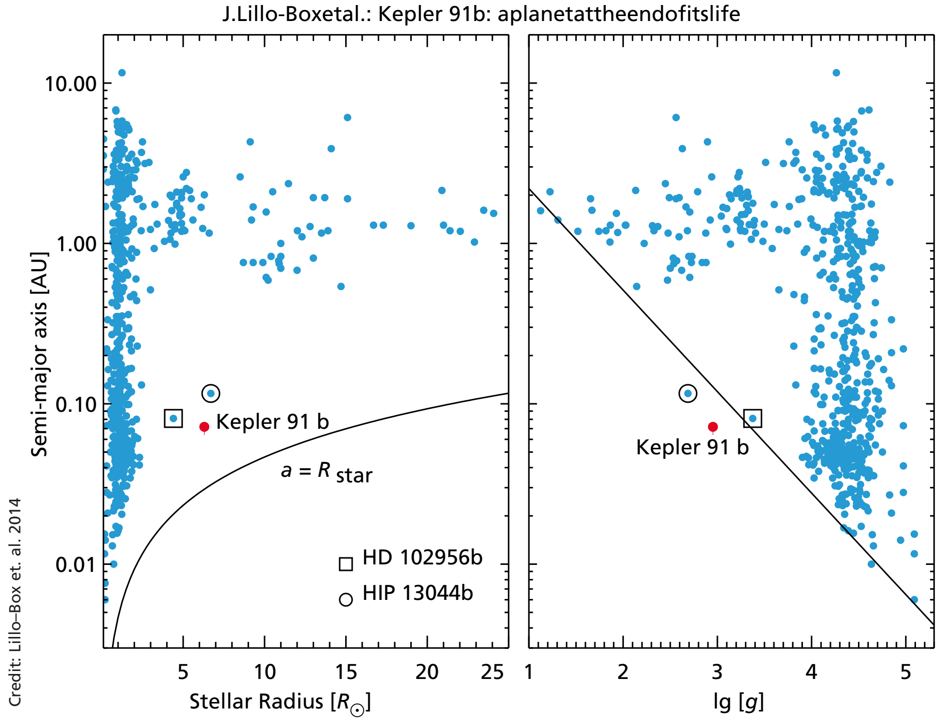


Fig. II.8.2: Comparing the properties of the Kepler-91 system with that of other exoplanets and their stars. In the diagram on the left, the semi-major axis of all confirmed planets (blue dots) is plotted against the stellar radius, in the diagram on the right against the star's surface gravity (that is, the value of the gravitational acceleration on the surface of the star). The extreme case in the diagram on the left, marked by the solid line, is that of a planet orbiting exactly at the surface of the star. The Kepler-91 system, marked with the red dot, has the planet closest to the stellar surface. In the diagram on the right, the solid line marks an empirical limit proposed by Nowak et al. in 2013. Kepler-91 and the intriguing HIP 13044 are the only planets safely on the other side of the putative limit.

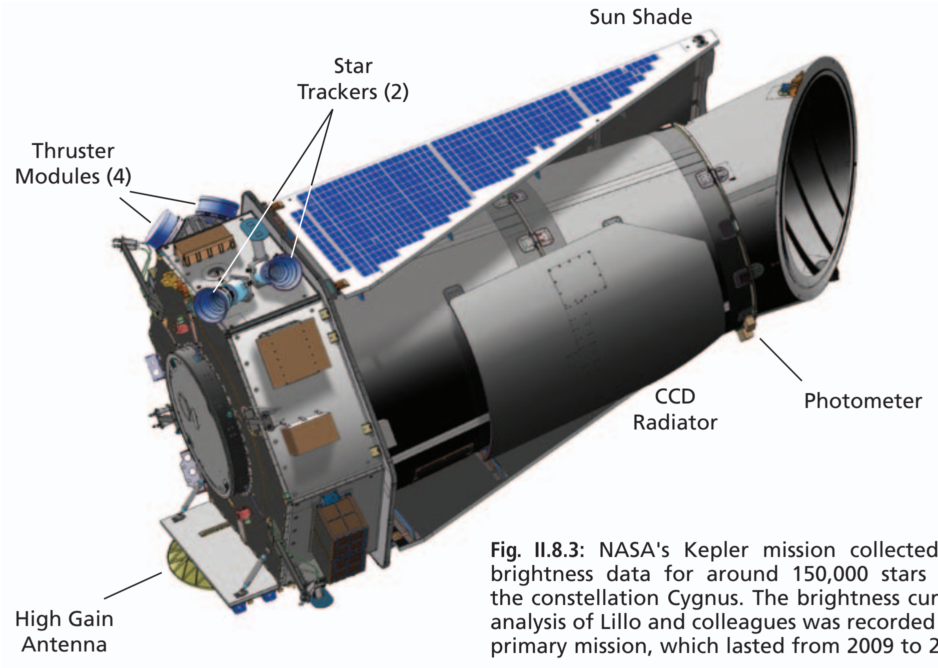
the Kepler team has also employed statistical methods to confirm stars with multiple planets – relying on the fact that it would be highly improbable for star spots and other effects to mimic the signal produced by a whole planetary system.

Instead, Lillo went a new way towards confirming (or eliminating) the planetary candidate. They had monitored the star's brightness very closely, carefully looking for effects that are not usually included in the analysis. For this, Lillo and his team mostly relied on the Kepler data, but also made additional observations with the AstraLux lucky imaging camera at the 2.2-m-telescope at Calar Alto. Their examination takes into account effects such as light produced by the planet; starlight reflected by the planet; deformations of the star produced by the planet's gravity, which cause brightness variations as the star shows us a larger or smaller profile, and brightness variations due to the star's motion caused by the planet's gravitational tug (»Doppler beaming«). In the end, they concluded that this was indeed a planet, which was then given the designation Kepler-91b.

Detailed light curve analyses are comparatively new and rare – and for a while, it was far from clear whether or not they were indeed reliable enough to detect planets. Two other groups of scientists (Esteves et al. 2013, Sliski & Kipping 2014) argued that Kepler-91 b might not be a planet at all; instead, it could be a dim star or brown dwarf.

Now spectroscopic observations with the newly operational spectrograph CAFE (Calar Alto Fiber-fed Echelle spectrograph) at Calar Alto observatory in Spain have provided independent evidence that Kepler-91b is indeed a planet. It has only 10% more mass than Jupiter; a value that fits in well with the results of the earlier analysis. Kepler-91b is the first firmly confirmed planet that has been detected by brightness variations and is orbiting a red giant star. Transits for giant stars are very difficult to detect: These stars are so large and bright that the brightness fluctuations caused by the planetary transit are very small indeed. At least at present, Kepler-91b with observations of a transit as well as of its radial velocity, and orbiting a red giant star, is unique.

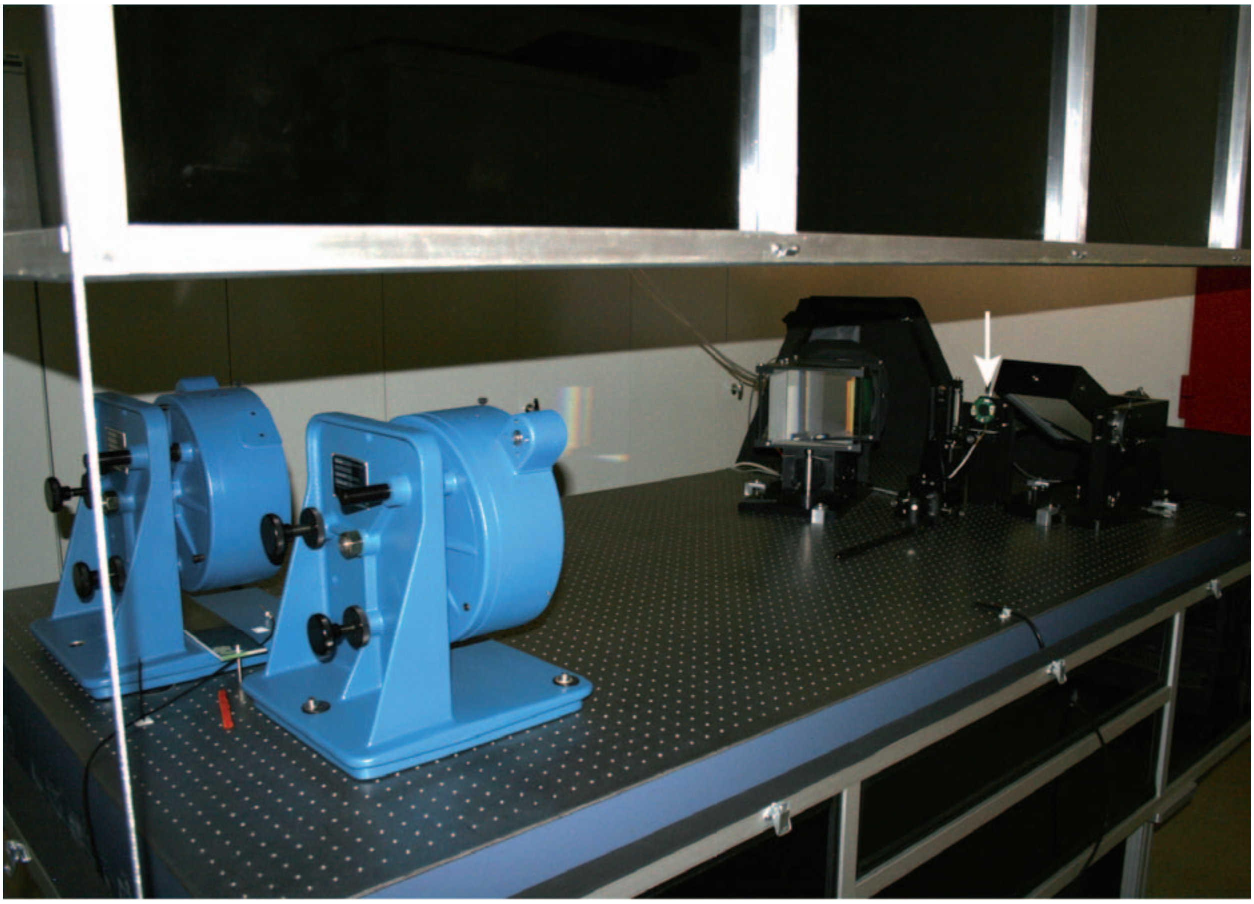
So far, this type of analysis had only been used on a handful of planets (as opposed to the hundreds of planets confirmed by other means) – so it's an interesting development to see its predictions for Kepler-91b confirmed by the more standard radial velocity measurements, providing a validation of what promises to become an important tool in the arsenal of exoplanet studies, using as it does a wealth of information that is missed by conventional analyses of brightness variations.



Credit: NASA

Fig. II.8.3: NASA's Kepler mission collected high-precision brightness data for around 150,000 stars in and around the constellation Cygnus. The brightness curve used for the analysis of Lillo and colleagues was recorded during Kepler's primary mission, which lasted from 2009 to 2013.

Fig. II.8.4: The CAFE spectrograph at Calar Alto with its protective cover lifted for inspection. Visible in the background on the right is the Echelle grating that performs the first part of the split, and on the left the two prisms in front of the camera, which perform the second part of the split. The blue mirrors front left collimate the light ("parallelize the light rays") as it is channeled from the entrance port (white arrow) to the Echelle grating to the prisms and the camera.



Credit: Jesús Aceituno

The observations are of particular significance for the staff at Calar Alto Observatory: CAFE, operational since 2011, is the first instrument built directly at the observatory, and this has been the first time an exoplanet has been confirmed with data from Calar Alto. The quality of the CAFE data went beyond the expectations of both the spectrograph's builders and the observers. This allowed for highly efficient use of the available observation time. The instrument's calibration process is still being improved, so even better performance can be expected for the future.

The excellent performance of CAFE bodes well for the instrument's successor, CARMENES, currently under construction by a German-Spanish consortium that includes the Max Planck Institute for Astronomy, the Instituto de Astrofísica de Andalucía, and Landessternwarte Königstuhl (Heidelberg University). From 2016 on, CARMENES will search for Earth-like planets around reddish stars known as M dwarfs.

Thomas Henning, Luigi Mancini,
Amelia Bayo and Simona Ciceri

with

Jorge Lillo-Box and David Barrado
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de Física e Astronomia, Universidade do Porto, Portugal),
Jesús Aceituno (Centro Astronómico Hispano-Alemán,
Calar Alto Observatory, Spain),
and Sebastian Sánchez (Instituto de Astronomía,
Universidad Nacional Autonóma, México)

Jorge Lillo-Box et al.: „Radial velocity confirmation of Kepler-91 b. Additional evidence of its planetary nature using the Calar Alto/CAFE instrument" in Astronomy & Astrophysics Volume 568 (2014), id.L1. DOI: 10.1051/0004-6361/201424587

II.9 Scientific Highlight

Uncloaking the King of the Milky Way: The Largest Star in our Home Galaxy's Largest Stellar Nursery

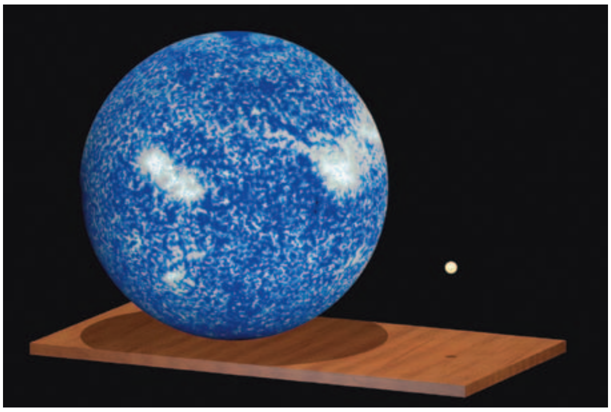
Astronomers led by Shiwei Wu of the Max Planck Institute for Astronomy have identified the most massive star in our home galaxy's largest stellar nursery, the star-forming region W49. The star, named W49nr1, has a mass between 100 and 180 times the mass of the sun. Only a few dozen of these very massive stars have been identified so far. As seen from earth, W49 is obscured by dense clouds of dust, and the astronomers had to rely on near-infrared images from ESO's New Technology Telescope and the Large Binocular Telescope to obtain suitable data. The discovery is hoped to shed light on the formation of massive stars, and on the role they play in the biggest star clusters.

The discovery of a new, very massive star is exciting to astronomers for more than one reason: Very massive stars, more than 100 times the mass of our own sun, are something of an astronomical mystery. They are very short-lived (a few million years compared to the 10 billion years of stars like our sun), which is one reason they are so rare. Among the billions of stars catalogued and examined by astronomers, these very massive specimens amount to no more than a few dozen, most of them discovered over the past few years.

Though rare, the massive stars have a decisive influence on their surroundings. They are extremely bright, giving off large amounts of highly energetic UV radiation as well as streams of particles (stellar wind). Typi-

Fig. II.9.1: A color image of the central area of W49. The massive star W49nr1 is indicated with a white arrow. The scale of one arc minute, shown on the bottom left, corresponds to only 1/30 of the apparent size of the Full Moon. The color composite was made by combining images taken with three special filters at different near infrared wavelengths (J, H, K).

Credit: S.-W. Wu, A. Bik, Th. Henning, A. Pasquali, W. Brandner, A. Stolte. J and H-band data originally published in Alves and Homeier 2003.



Credit: MPIA / Axel M. Quetz

Fig. II.9.2: As shown in this artist's impression, the diameter of the blueish giant star W49nr1 is 25.5 times that of our sun.

cally, such a star will create a bubble around itself, ionizing any nearby gas, and pushing more distant gas ever farther away. Some of this pushed-away gas might actually cause distant gas clouds to collapse, triggering the birth of new stars.

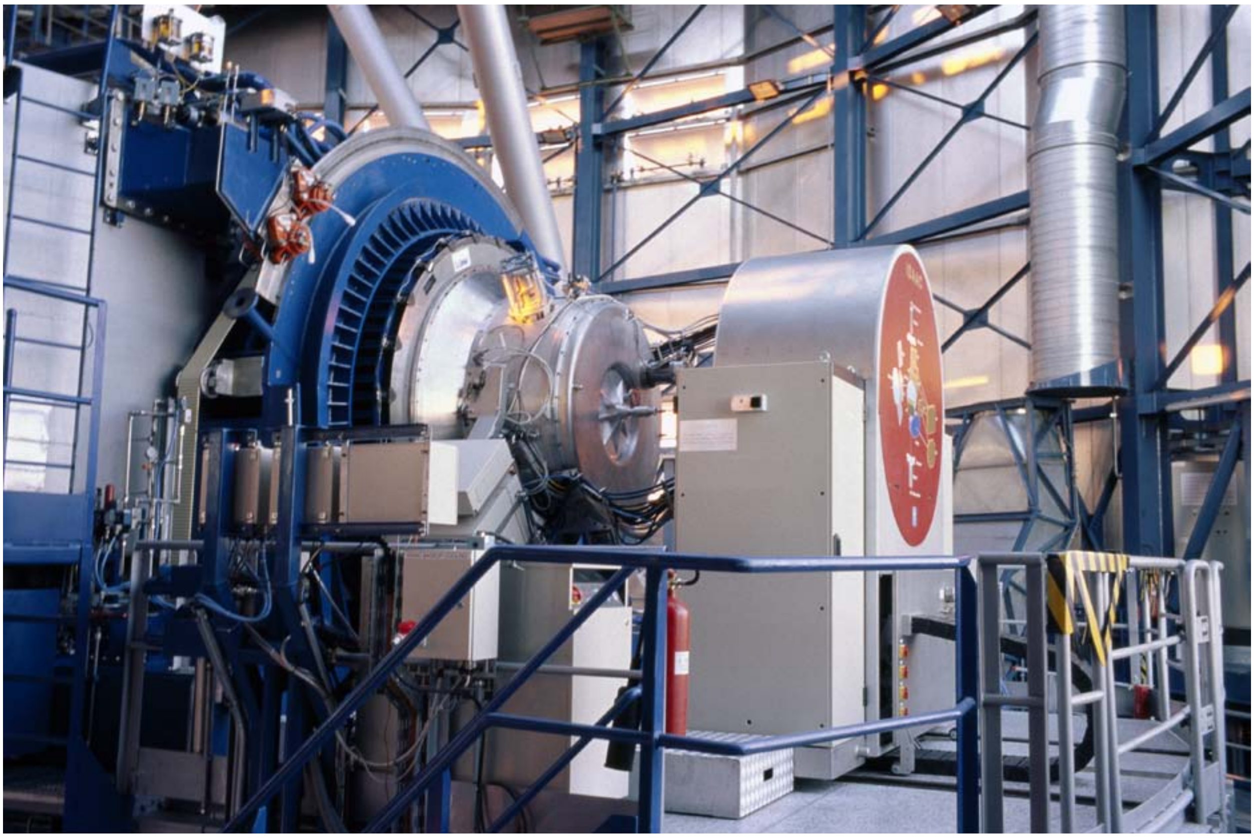
Until a few years ago, there was even doubt whether such stars could form at all. Theorists have only quite recently managed to simulate the genesis of these massive bodies, and there are now several competing explanations for very massive star formation. In some models, such a star is the result of the merger between two stars forming in an extended star cluster. Up to now, there had only been three clusters (NGC 3603 and the Arches Cluster in our galaxy, R136 in the Large Magellanic Cloud) where such massive stars had actually been found.

Now, a team of astronomers lead by Shiwei Wu from the Max Planck Institute for Astronomy (MPIA) has discovered such a massive star, and not in any location, but in the largest star-forming region known in our Milky Way galaxy, which is called W49. The discovery was a challenging task: W49 is located at a distance of 36,000 light-years (11.1 kpc), almost half-way across our home galaxy, cloaked by the dust of two spiral arms that lie between us and the cluster.

Shiwei Wu explains: »Because W49 is hidden behind huge regions of interstellar dust, only one trillionth of the visible light it sends in our direction actually reaches earth. That’s why we observed the cluster’s infrared light, which can pass through dust almost unhindered.«

The study is based on several sets of infrared observations. The principal observation was a medium-resolution K-band spectrum taken with the ISAAC instrument

Fig. II.9.3: ISAAC, the Infrared Spectrometer And Array Camera, at that time still mounted on the VLT Unit Telescope UT1. ISAAC analyses the infrared light with wavelengths from 1 to 5 microns. It can both take images and disperse the light into spectra. The instrument's optics and detector are kept at very low temperature in a vacuum vessel. This instrument produced the spectrum of W49nr1 that was used to determine the star's gigantic mass.



Credit: ESO

mounted at ESO's Very Large Telescope in Chile. Infrared images were obtained with SOFI at the New Technology Telescope at ESO's La Silla Observatory (J- and H-Band), and with LUCI mounted at the Large Binocular Telescope in Arizona (K-Band). From this data, the astronomers could determine the star's type (»O2-3.5If* star«) and use this information and the star's measured brightness to estimate its temperature and total light emission. Comparison with models for stellar evolution give an estimate of the star's mass between 100 and 180 solar masses.

Because of the cluster's size, W49 is one of the most important sites within our galaxy for studying the formation and evolution of very massive stars – and with W49nr1, the astronomers have now identified the cluster's key object. With this and future observations, they have hopes of settling one of astronomy's weightiest open questions: the birth of our galaxy's most massive stars.

Shiwei Wu, Thomas Henning, Arjan Bik (auch Universität Stockholm) und Wolfgang Brandner

with

Anna Pasquali (ZAH, Heidelberg University) and Andrea Stolte (Argelander Institute for Astronomy, Bonn)

Shiwei Wu et al.: »The discovery of a very massive star in W49« in Astronomy & Astrophysics Volume 568 (2014), Article number L13. DOI: 10.1051/0004-6361/201424154

II.10 Scientific Highlight

The Smallest Galaxy Known to Harbor a Supermassive Black Hole

A group of astronomers including MPIA's Remco van den Bosch and Nadine Neumayer have found that an ultracompact dwarf galaxy close to the giant galaxy M60 harbors a supermassive black hole. This is the smallest galaxy known to possess such a central black hole. The finding suggests that all dwarf galaxies of this kind could be the remnants of considerably larger precursor galaxies, which had most of their mass stripped away in a galaxy collision.

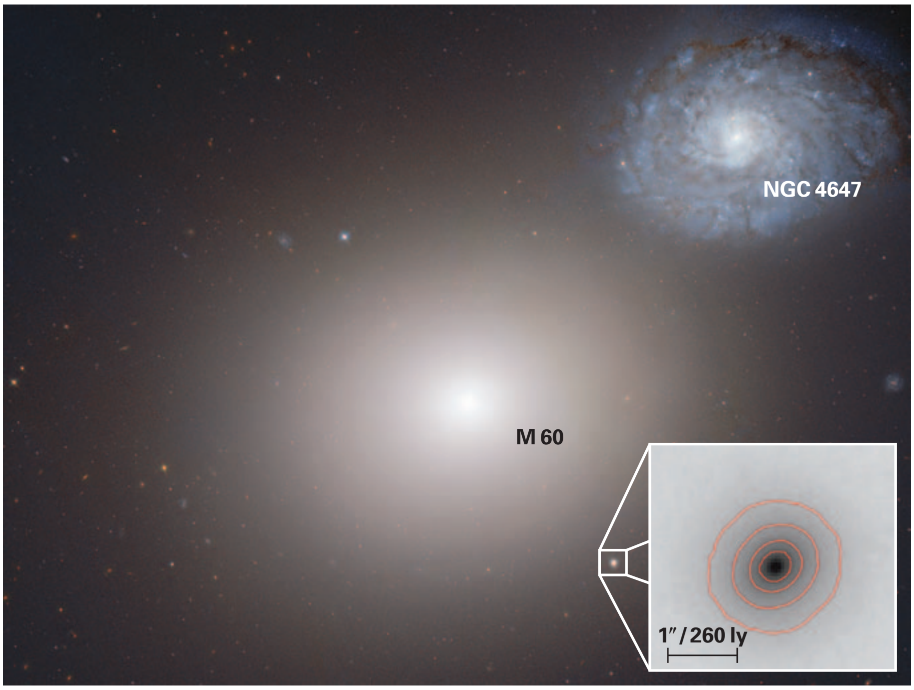
In a black hole, mass is concentrated in a region so small that not even light can escape its gravitational grasp. Smaller black holes, with a mass amounting to a few times the mass of the sun, are formed when the core regions of massive stars collapse at the end of their lives. Supermassive black holes, on the other hand, with masses of between a million and some billion times the mass of the sun can be found in the central regions of galaxies. In fact, traces of such central black holes can be found in all galaxies, but so far have been missing in those that are unusually small.

This fact is an important piece of a puzzle involving so-called ultra-compact dwarf galaxies – some of the most dense star systems in the universe. Dwarf galaxies are only a few hundred light-years in size. In contrast, larger galaxies, such as our own Milky Way, can have diameters of 100,000 light-years or more!

The origin of ultra-compact dwarf galaxies is a matter of ongoing discussion. Are they perhaps the remnants of larger precursor galaxies, stripped of all but their innermost regions in collisions with other galaxies? Or are they perhaps not galaxies at all? Are they, instead, the largest specimens of what is known as globular clusters – concentrated groups of usually around 100,000 stars that are part of larger galaxies, and whose stars have usually formed around the same time? The halo of our Milky Way alone contains around 200 of these globular clusters, and some galaxies can contain thousands of these objects.

When it comes to the origin of ultra-compact dwarf galaxies, the absence or presence of the central black hole would be an important clue. In particular, a black hole

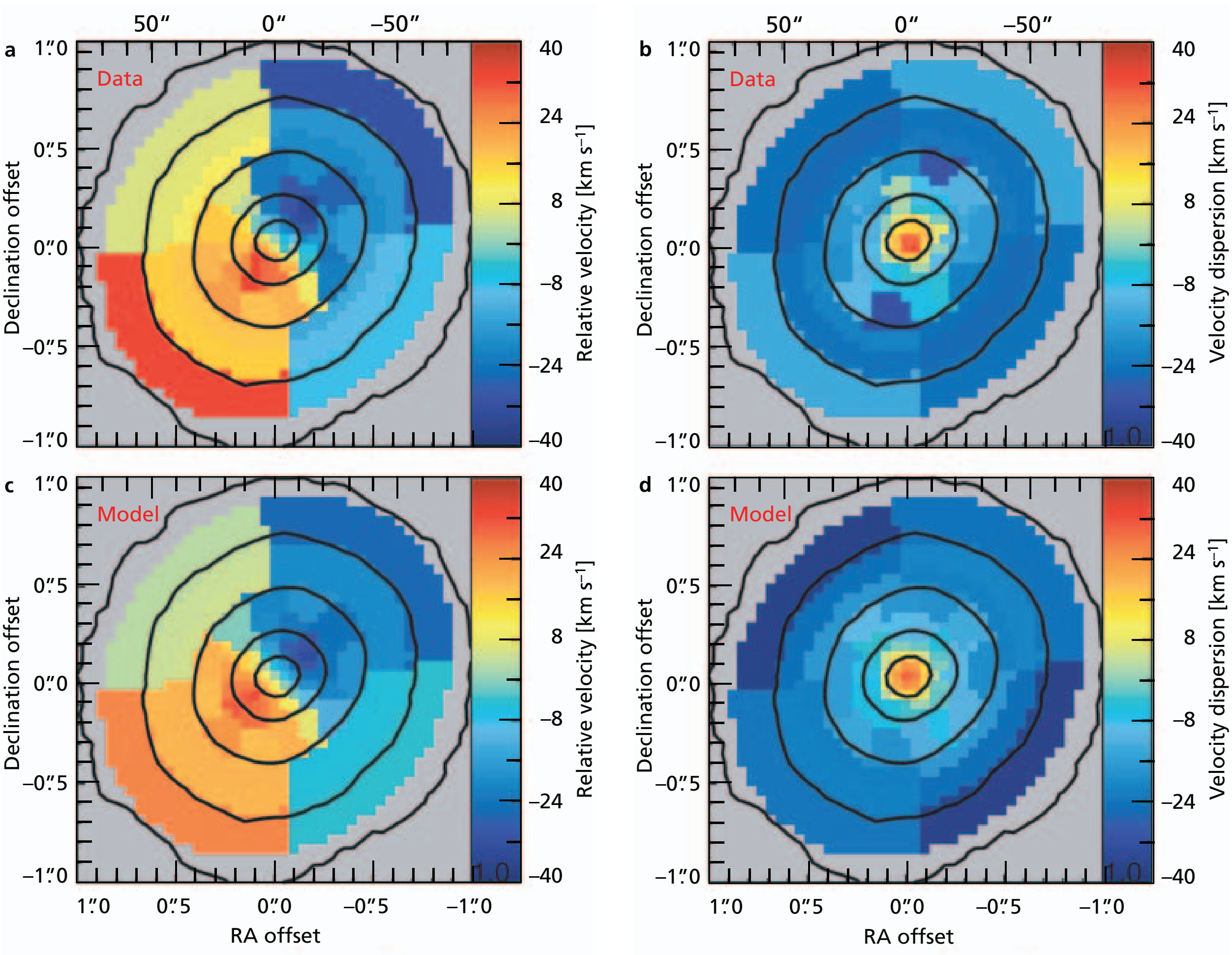
Fig. II.10.1: This image by the Hubble Space Telescope shows M 60 (center), a large galaxy in the constellation Virgo and the ultra-compact dwarf galaxy M60-UCD1 (box and zoomed-in, inverted inset), which hosts the newly discovered supermassive black hole. The spiral galaxy NGC 4647 (top right) is another member of the group.



Credit: NASA / Space Telescope Science Institute/European Space Agency that is comparatively massive for a galaxy of the given size would be an indication that we are indeed looking at the remnant of a markedly larger precursor galaxy (with a black hole that correspondingly large). More generally, such dwarf galaxies do appear to contain more mass than would be expected from their luminosity.

With 140 million solar masses, the ultra-compact dwarf galaxy M60-UCD1 is one of the most massive known systems of that type. The galaxy is close to another, much larger galaxy known as M60, in the constellation Virgo (cf. figure II.10.1). The distance between the dwarf galaxy and the center of M60 amounts to a mere 22 000 light-years, which is less than the distance between our Solar System and the center of our home galaxy, the Milky Way. The distance of M60 and M60-UCD1 from us amounts to 54 million light-years.

M60-UCD1 came under study by a group of astronomers led by Anil Seth of the University of Utah; the group also included MPIA's Remco van den Bosch and Nadine Neumayer. The galaxy had come to the astronomers' attention as a compact X-ray source – another indication that there is a black hole involved: Whenever gas falls into a black hole, it collects in a so-called accretion disk close to the black hole's surface before taking the plunge. The disk gets heated to extremely high temperatures as infalling gas deposits more and more energy; in consequence, it emits highly energetic thermal radiation, including X-rays. This is a well-known phenomenon by which galactic black holes are responsible for some of the brightest sources of light in the cosmos, known as quasars or, more generally, as active galactic nuclei (AGN).



Credit: Seth et al. 2014

Fig. II.10.2: Observation (top row) and model data (bottom row) for stellar motion in the ultra-compact dwarf galaxy M60-UCD1. The images in the left-hand column show larger-scale stellar motion. The colors indicate radial velocity, with motion directly towards us represented by blue and light blue, motion away from us as yellow, orange and red. Image (a) shows observational data, dominated by the rotation of the galaxy: We view M60-UCD1 somewhat from the side, so the regions on the upper right rotate away from us, the regions bottom left towards us. Part (b) shows the observed velocity dispersion. It is particularly large in the innermost regions, reaching values of more than a hundred kilometer per second. The bottom row shows the values for the radial velocities (c) and velocity dispersion (d) as predicted by the best-fitting dynamical model. In particular, these models can only reproduce the central velocity dispersion maximum adequately when they include a central black hole.

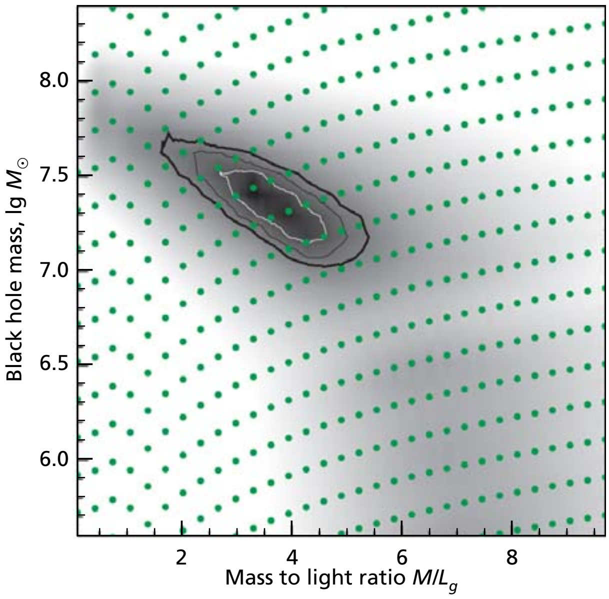
Did M60-UCD1 contain a central, supermassive black hole, then? To make sure, the astronomers observed the galaxy using the Gemini North Telescope, an 8 meter mirror telescope on top of Mauna Kea on Hawaii. From their observations, they determined the velocities of stars in the dwarf galaxy, paying particular attention to those stars orbiting the galaxy's central regions. The speed of those stars depends on the galaxy's mass distribution. By modeling those speeds, it is possible to deduce the mass distribution, and in particular make an estimate for the mass in the galaxy's innermost regions. That mass, in turn, is an indication of whether or not the galaxy contains a central black hole, and also allows estimates of the black hole's mass.

The observations, made in February and May 2014 with the NIFS instrument at the Gemini North Telescope, produced spectra – the rainbow-light decomposition of light into myriads of component colors – for roughly 1400 separate regions within the small galaxy. Such spectra contain absorption lines, narrow wavelength regions where the object's output of light is greatly reduced. Absorption line wavelengths are governed by atomic and molecular physics, and can be measured in the lab. Deviations between lab wavelengths and observed wavelengths are a sign of an object's motion towards us or away from us (radial velocity), according to the Doppler effect. In this way, the astronomers were able to produce a radial velocity map for the galaxy (Figure II.10.2a).

Each measurement reflects the average stellar motion within the region observed. The average deviation of the individual stars from this average motion, known as velocity dispersion, influences the width of the absorption lines: A greater variety of motions corresponds to broader lines. These line-widths, too, can be mapped for all the regions under scrutiny, and the associated values for the velocity dispersion make for a complementary type of motion map for the galaxy (Figure II.10.2b).

These maps can be compared with simple models for stellar motion within the galaxy. The simplest models that are powerful enough to explain the data are as follows: The galaxy is modeled as an ellipsoid (an oblate sphere). The model assumes that the relationship between luminosity and mass is constant for all the stars within the galaxy. The stellar distribution can be deduced from images such as the one in Figure II.10.1, making sure the model reproduces the galaxy's luminosity profile. This leaves only a few free parameters: the galaxy's orientation relative to us, the value for the stars' constant ratio between luminosity and mass, and the mass of a possible central black hole.

For these parameters, a plethora of possible combinations of values is tried out. For each combination, the radial velocity and velocity dispersion maps, as predicted by the model, are calculated. The results are tested against the observed maps for these quantities. The discrepancies between simulated and observed maps are added



Credit: Seth et al. 2014

Fig. II.10.3: Part of the parameter space of the models. Each point in this plane corresponds to a specific value for the black hole mass (y-axis, logarithmic scaling) and a specific mass-to-light ratio (x-axis, g-band filter). The green dots indicate those (discrete) values of the mass-to-light ratio and the black hole mass at which model predictions were compared with the observational data. The grayscale shading indicates the goodness-of-fit for the various parameter choices. (The contours indicate 1σ [white], 2σ, 3σ [black, thick] confidence levels for two degrees of freedom.) The plot clearly shows that, in order to produce the observed data, models need to assume the presence of a central black hole with a mass between 10 and 30 million solar masses.

up, yielding a measure for the explanatory power of each particular combination of values. Finally, by comparing the various fits, the optimal combination of parameter values is determined. Figure 3 shows the goodness-of-fit for a region of values for the luminosity-mass ratio and the central black hole mass; Figures 2c and 2d show the radial velocity and dispersion maps for the best-fitting model.

The modeling was performed by MPIA's Remco van den Bosch. The results were clear: Only models that included a black hole with a mass of around 21 million solar masses were capable of reproducing the observed data (cf. Figure II.10.3). With an average speed of 370,000 kilometers per second, the stars in the galaxy's innermost regions are considerably faster than one would expect without the presence of a black hole. The only possible alternative could be a population of very massive stars in the galaxy's central regions. However, using images taken with the Hubble Space Telescope, the researchers were able to show that this is a highly unlikely prospect – mass in the galactic center of M60-UCD1 is concentrated in a region that would be exceptionally small for such a star cluster.

Gathering together all the pieces of the puzzle, there is strong evidence that M60-UCD1 indeed possesses a central black hole with 21 million solar masses – the smallest and lightest galaxy for which a black hole could be detected so far.

Whereas the origin of stellar-mass black holes is fairly well understood (stellar collapse, cf. above), the origin of supermassive black holes in the centers of galaxies is still an open question. Apparently, their formation is tied in with the formation of the galaxy as a whole. In fact, a few years ago astronomers discovered an unexpected correlation between a galaxy's total mass and the mass of its central black hole – two values orders of magnitudes apart, but nevertheless related.

This correlation predicts a much smaller ratio between central black hole and galaxy mass than is the case for M60-UCD1. Our home galaxy, the Milky Way, is a typical example: With a supermassive central black hole with a bit over 4 million solar masses, the Milky Way's central black hole accounts for less than 0,01 percent of the total galaxy mass.

Compare this with M60-UCD1 and its 21 million solar mass black hole, which amounts to roughly 15 per cent, about one sevenths, of the dwarf galaxy's total mass of 140 million solar masses. For the 75 galaxies that had their black hole masses measured reliably using stellar motion analysis, only a single one comes close to this sizeable fraction (van den Bosch et al. 2012; cf. the MPIA annual report 2012, section II.3).

The comparatively large central black hole mass suggests that M60-UCD1 very likely was a much larger galaxy in the past – in line with one of the evolution scenarios for ultra-compact dwarf galaxies as the remnants of larger galaxies. There is a similar relation between stellar mass in the central regions of a galaxy and the total mass that points in the same direction; taken together, the two relations suggest that M60-UCD1 was originally an elliptical galaxy with a total mass of around 10 billion solar masses. When that galaxy came too close to M60, gravitational interactions would have stripped it of most of its stars and dark matter.

The dwarf galaxy's orbit around M60 is not known with any certainty. It remains possible for the M60-UCD1 to be swallowed up by M60 completely, merging into the larger galaxy altogether. M60 is already one of the largest galaxies we know in the local universe. Its central black hole has a mass of around 4.5 billion solar masses – a factor 1000 more than the black hole at the center of our own Milky Way galaxy.

To begin with, M60-UCD1 is a single data point. But it strengthens the more general model of ultra-compact dwarf galaxies as the remnants of much larger precursor galaxies, stripped of most of their stars and mass (and their original structure) by galaxy collisions. This suggests a natural direction for future research, namely that

Fig. II.10.4: The Gemini North Telescope on Mauna Kea, Hawaii. The laser beam is used to detect turbulences in the earth's atmosphere, allowing for real-time corrections of the observations using adaptive optics.

Credit: Gemini Observatory/Association of Universities for Research in Astronomy of searching for central black holes – and in particular, over-sized black holes – in other ultra-compact dwarfs, as well. If M60-UCD1 is representative of ultra-compact dwarf galaxies in general, then there should be about twice as many supermassive black holes in the observable universe than previously thought.

Even our home galaxy contains a candidate for such a remnant: Omega Centauri, the largest stellar cluster in the Milky Way, which is likely to contain a central black hole. Omega Centauri is probably the core region of a galaxy that has been swallowed by the Milky Way in the course of galaxy evolution.

Remco van den Bosch and Nadine Neumayer
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with

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Jean Brodie (UC Santa Cruz),
Matthias J. Frank (ZAH, Universität Heidelberg),
and Jonelle L. Walsh (University of Texas at Austin)

Anil C. Seth et al.: »A supermassive black hole in an ultra-compact dwarf galaxy« in Nature Vol. 513 (2014), pp. 398-400.
DOI: 10.1038/nature13762

»CT Scan« of Distant Universe Reveals Cosmic Web in 3D

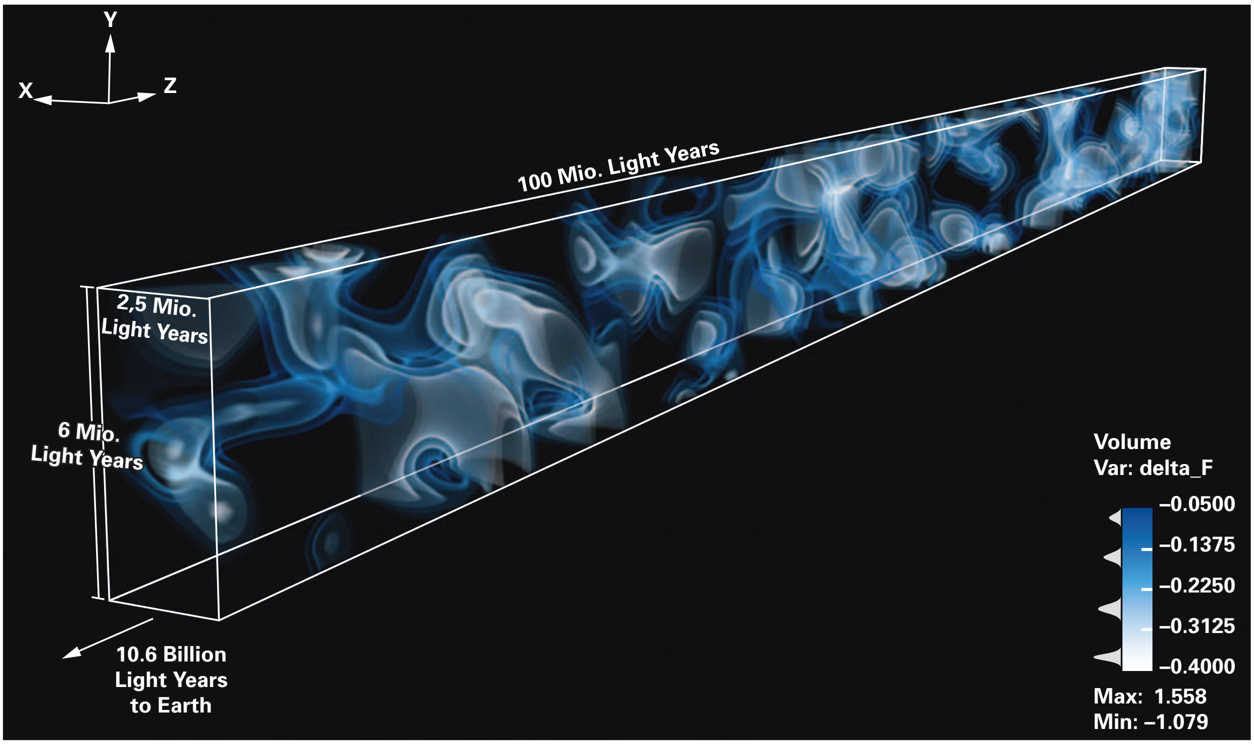
A team led by astronomers from the Max Planck Institute for Astronomy has created the first three-dimensional map of the »adolescent« Universe, just 3 billion years after the Big Bang. Applying a new technique analogous to x-ray computer-tomographic (CT) imaging used in medicine, the researchers measured the light from a dense grid of distant background galaxies probing the Universe from multiple locations, and then combined the data to construct a 3-D map of the intervening matter. This map, millions of light years across, provides a tantalizing glimpse of large structures in the »cosmic web«, which forms the backbone of cosmic structure.

On the largest scales, matter in the Universe is arranged in a vast network of filamentary structures known as the »cosmic web«, its tangled strands spanning hundreds of millions of light years. Dark matter, which emits no light, forms the backbone of this web, which is also suffused with primordial hydrogen gas left over from the Big Bang. Galaxies like our own Milky Way are embedded inside this web, but fill only a tiny fraction of its volume.

The cosmic web is as elusive as it is important: dark matter is invisible, and the embedded hydrogen gas is so rarefied that it emits little light. Studies of this elusive gas make use of a principle similar to a medical CT scan, which reconstructs a three-dimensional image of the human body from the X-rays passing through a patient: the astronomers rely on background lighting by extremely distant objects whose light passes through the cosmic web's hydrogen gas.

For decades, the only distant light-sources available for this kind of study of the cosmic web were quasars. Quasars are the nuclei of distant galaxies which, powered

Fig. II.11.1: 3D map of the cosmic web at a distance of 10.8 billion light years from earth. The map was generated from imprints of hydrogen gas observed in the spectrum of 24 background galaxies, which are located behind the volume being mapped. This is the first time that large-scale structures in such a distant part of the Universe have been mapped directly. The coloring represents the density of hydrogen gas tracing the cosmic web, with brighter colors representing higher density.



Credit: Casey Stark (UC Berkeley) und Khee-Gan Lee (MPIA) by the infall of matter onto a supermassive black hole, shine as the brightest objects in the Universe. As their light travels towards earth, it encounters the rarefied cosmic gas filling the void between galaxies, and some of the light is absorbed. Crucially, this absorption occurs at very specific frequencies. When astronomers on earth split a quasar's light, rainbow-like, into its different component colors, the absorption creates a characteristic pattern in the spectrum, narrow darker regions which astronomers call absorption lines. The pattern and shape of these lines allow astronomers to study the distribution of the absorbing gas.

Since our universe is expanding, the location of a gas cloud's absorption lines within the spectrum depends on the cloud's distance from earth (»cosmological redshift«). This is because the quasar light stretches as it travels toward earth, thus as the light passes through various gas clouds the absorption signature is imprinted on a different region of the quasar's spectrum. The quasar light thus bears the imprint of all the clouds it encountered; for each cloud, the position of the absorption line in the spectrum contains information about the cloud's distance from earth. The most prominent of these absorption patterns is caused by the Lyman-alpha absorption line of hydrogen gas. Collectively, the pattern of Lyman-alpha lines, each associated with a different cloud, is known as the *»Lyman-alpha forest«*.

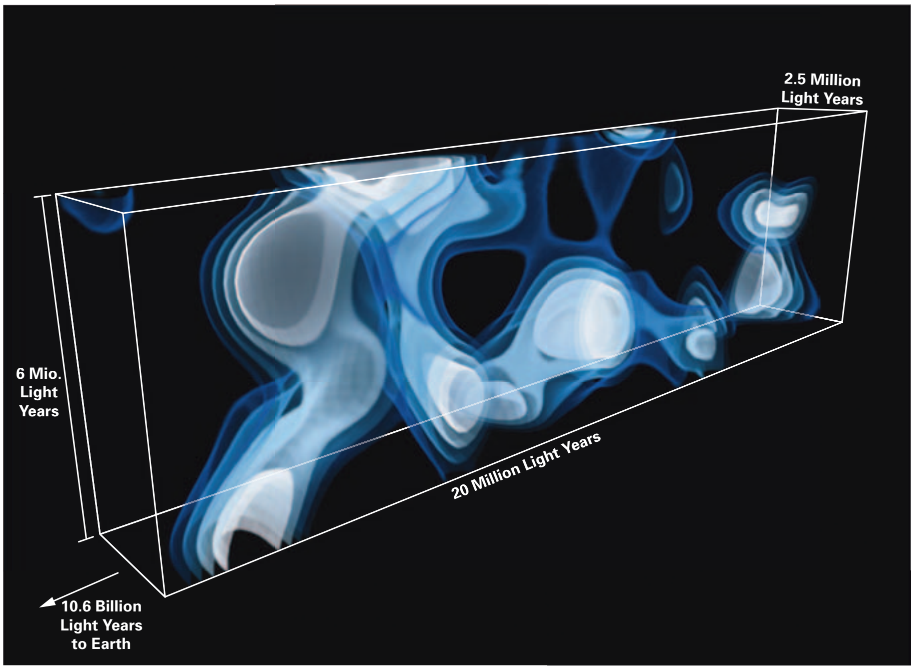
But bright quasars are very rare, and hence sparse on the sky. In consequence, the sightlines where the cosmic web can be traced using quasar light are so few and far between that they do not provide nearly enough information to construct a truly three-dimensional map.

For this reason, astronomers had long considered using the combined starlight of distant galaxies as an alternative background light source. Galaxies are nearly 100 times more numerous than quasars. If they could be used as backlights for absorption studies, this would enable a high-fidelity 3D tomographic mapping of cosmic structure – similar to computer tomography (CT) methods used in medical imaging. The snag was that galaxies are about 15 times fainter than quasars. The prevailing view was that this is simply not bright enough for the experiment to be feasible, and it appeared that the next generation of gargantuan telescopes, such as the European Extremely Large Telescope (E-ELT) with a 40m mirror diameter, would be required to construct 3D maps of the cosmic web.

But quite unexpectedly, when Khee-Gan Lee, a postdoctoral researcher at the Max Planck Institute for Astronomy, sat down to calculate the observational requirements for a galaxy-based 3D map, his results showed that such a map should indeed be possible using current telescopes – although the resulting 3D map would necessarily have a lower resolution than for these telescopes' larger descendants.

Lee and his colleagues obtained observing time on one of the largest telescopes in the world: the 10m-diameter Keck I telescope at the W. M. Keck Observatory on Mau-

Fig. II.11.2: Close-up of the 3D map of the distant Universe created by MPIA and UC astronomers. The filamentary structures seen in this map span distances of millions of light years, and represent the cosmic web at an earlier stage of cosmic evolution when the Universe was less than a quarter of its current age. The region of space seen here is at a distance of 10.8 billion lightyears from earth. The coloring represents the density of hydrogen gas tracing the cosmic web, with brighter colors representing higher density.



Credit: Casey Stark (UC Berkeley) and Khee-Gan Lee (MPIA) na Kea, Hawaii. As their target area, they chose part of the COSMOS field in the constellation Sextans. Over the past years, this part of the sky has been targeted repeatedly with multiple instruments and telescopes. It provides excellent conditions for deep insight into the distant cosmos far beyond our own home galaxy.

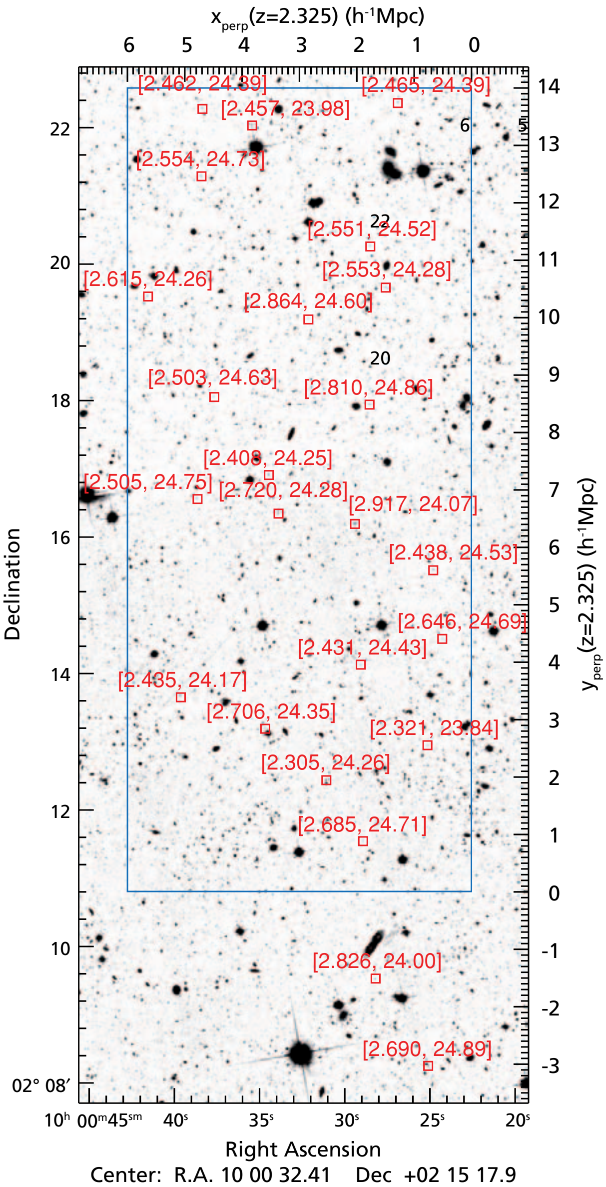
During their observations, carried out with the Low-Resolution Imaging Spectrograph (LRIS) on the 10m-diameter Keck I telescope, the astronomers were plagued by a problem much closer to home than their objects of study: inclement weather, which drastically reduced their effective observation time. In the end, the group was able to obtain a mere four hours of good data. But even a quick inspection as the data came off the telescope raised the astronomers' hopes that their experiment had worked.

More thorough analysis confirmed that the data the astronomers had collected was completely unprecedented. Their absorption measurements using 24 faint background galaxies provided sufficient coverage of a small patch of the sky to be combined into a 3D map of the foreground cosmic web. A crucial element in the analysis was the computer algorithm used to create the 3D map: due to the large amount of data, a naïve implementation of the map-making procedure would have required an inordinate amount of computing time. Fortunately, team members Casey Stark and Martin White (UC Berkeley and Lawrence Berkeley National Lab) devised a new fast algorithm that could create the map within minutes. Stark and White realized they could simplify the computations by tailoring them to the particular problem at hand. The resulting algorithm required significantly less computer memory before, and a calculation that had previously required a supercomputer now ran on an ordinary laptop.

The resulting map of hydrogen absorption reveals a three-dimensional section of the universe 11 billions light years away – the first time the cosmic web has been mapped at such a vast distance. Since observing to such immense distances is also looking back in time, the map reveals the early stages of cosmic structure formation when the Universe was only a quarter of its current age, less than 3 billion years after the big bang (redshift z=2.3) during an era when the galaxies were undergoing a major »growth spurt«. At the time of the snapshot, the region that was mapped measured roughly 2.5 million by 6 million by 100 million light years across (the latter value describes the radial extent: the most distant parts of this region are 100 million years more distant from us than the nearest parts). Since then, cosmic expansion has made all its length scales expand by a factor of 3.3. The map provides a tantalizing glimpse of giant filamentary structures extending across millions of light years.

Compared to previous maps, the new map constitutes a major leap forward. Earlier maps of the cosmic web had relied on using the positions of individual galaxies as tracers – map a sufficient number of such galaxy positions, and you should be able to perceive the shape of the underlying filaments of the cosmic map. But the only existing maps covering large volumes have been confined to the local universe (mapping galaxies up to distances of 3 billion light years, z = 0.3), while smaller maps have co-

Fig. II.11.3: Image of the region of the sky for which the map was reconstructed, taken with the Hubble Space Telescope's Advanced Camera for Surveys (F814W, mosaic). The blue box corresponds to the transverse cross-section of the three-dimensional block in figure 1. Each little red box marks one of the galaxies whose spectra were used for the three-dimensional reconstruction, with each galaxy's redshift and brightness (g-band) noted in red above the box. Together, these sources cover a redshift range between z = 2.15 and z = 2.40 for the Lyman-Alpha lines. The top and right axes indicate a coordinate system whose origin is the bottom right corner of the map area (=of the blue box), and which translates angular separation into distances at redshift z = 2.325 (transverse co-moving separation). In this way, one can read off estimates of the galaxies' transverse separations directly.



Credit: Koekemoer et al. 2007 and Lee et al. 2014 vered distances of up to 7 billion light years ($z = 1$). At even larger distances, where the galaxies are fainter, maps of this kind – one data point per galaxy – are far too sparse and much too inefficient to produce a high-fidelity map. In contrast, the Lyman-alpha absorption technique pioneered by Lee and his colleagues – one line-of-sight per galaxy – proves much more efficient, since it continuously probes the distribution of the cosmic web over hundreds of millions of light years in front of each galaxy, allowing an efficient way of mapping the Universe even at this vast distance.

The new observations also serve as a successful feasibility study for a much more extensive survey. The elongated shape of the map is due merely to the fact that the observations were limited by bad weather – the astronomers simply did not have sufficient observing time to cover a larger patch of sky, and thus a larger volume of space. The technique itself is remarkably efficient, and it would not take long to obtain enough data to cover volumes hundreds of millions of light years on a side. This is the goal of the more extensive CLAMATO survey (COSMOS Lyman-Alpha Mapping And Tomography Observations), which is aimed at creating a tomographic map covering one square degree (=50%) of the Cosmic Evolution Survey (COSMOS) field, one of the most extensively studied regions in the sky.

From this much larger map – the next step on the agenda – the astronomers hope to glean insights not only about the structure of the adolescent cosmic web, but also about its function. During that period of cosmic history, galaxies underwent rapid growth; the cosmic web plays a crucial role in funneling gas, the raw material of star formation, onto the galaxies. Previous studies have been able to map the cosmic web in the immediate vicinity of a bright quasar, showing the inflow of pristine cosmic gas (cf. MPIA Annual Report 2013, section II.8) onto galaxies; a larger-scale map would enable astronomers to explore such processes in 3D, follow the flows over longer distances and to reconstruct the cosmic logistics of star formation on a large scale.

Furthermore, large tomographic maps would allow astronomers to study the roots of cosmic inequality: One of the most striking features of the present-day Universe is the dichotomy between »rich« massive clusters of galaxies and the huge surrounding voids that are almost completely starved of matter. The 3D maps from the new technique will allow astronomers to identify proto-clusters and proto-voids in the distant Universe, at a time when the universe was a quarter of its current age, or less. Such maps would provide a unique historical record on how the galaxy clusters and voids grew from the tiny inhomogeneities nascent in the Big Bang.

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David Schlegel
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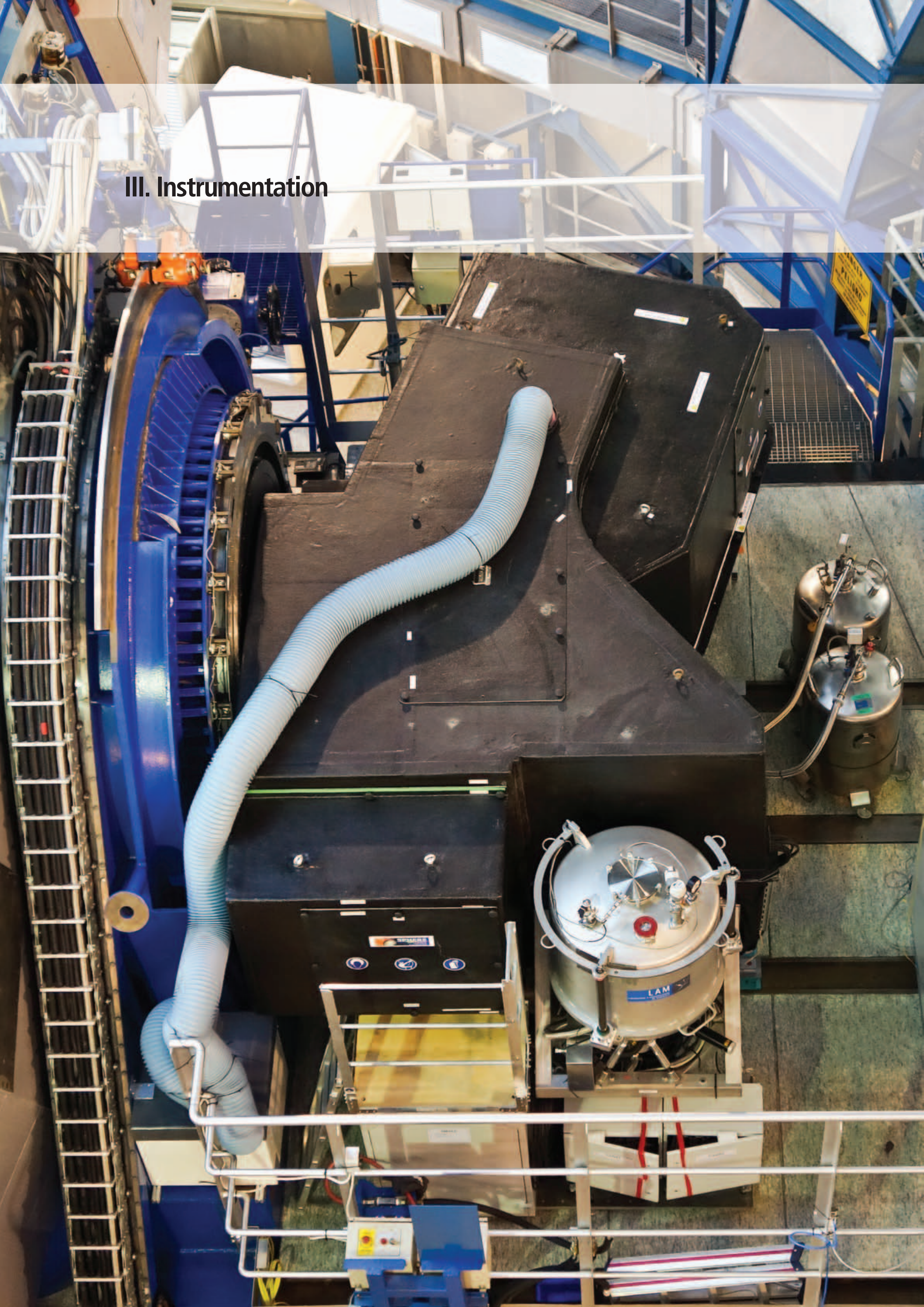
K.G. Lee et al. 2014: »Ly Forest Tomography from Background Galaxies: The first Megaparsec-Resolution Large-Scale Structure Map at z < 2« in Astrophysical Journal Letters Vol. 795, article id L12. DOI: 10.1088/2041-8205/795/1/L12

III. Instrumentation



III.1 Overview

Instrumentation for Ground-based Astronomy

In 2014, MPIA activities in the area of ground-based instrumentation concentrated on spectroscopy, high-fidelity imaging, and interferometric instruments for the ESO telescopes VLT/VLTI and VISTA and for the Large Binocular Telescope (LBT), as well as survey instruments for Calar Alto. MPIA is also involved in studies for future instruments for the European Extermely Large Telescope (E-ELT), a planned next generation telescope with a main mirror 39 meters in diameter.

Instrumentation for the Large Binocular Telescope (LBT)

LUCI 1 and LUCI 2 are two near-infrared cryogenic imaging cameras and multi-object spectrographs for the Large Binocular Telescope (LBT) on Mount Graham in Arizona. The two instruments were built in collaboration with the Landessternwarte Heidelberg, the Max Planck Institute for Extraterrestrial Physics in Garching, the University of Bochum, and the Fachhochschule for Technology and Design in Mannheim.

The LUCI instruments provide a 4×4 field-of-view in seeing limited mode - a bit over 1/60 of the apparent area of the full moon in the sky, and extremely wide for an astronomical camera at a large telescope like the LBT.

At the beginning of 2010, the first excellent spectra and images taken with LUCI 1 were published. Particularly remarkable about these instruments is the use they make of adaptive optics – real-time deformable mirrors that can reverse most of the degradation experienced by astronomical images as a distant object's light passes through the Earth's atmosphere.

With the adaptive secondary mirrors of the telescope, diffraction-limited performance (that is, observations virtually free of the atmosphere's disturbing influence) over a field of about 0.'5 × 0.'5 is possible. In fall 2014, LUCI 2 was upgraded to full adaptive optics functionality. LUCI 1 is currently undergoing the same upgrade. Adaptive optics permits users to achieve spectral resolving powers of several tens of thousands. The various scientific applications for the multi-mode LUCI instruments include the study of star formation in nearby galaxies.

Adaptive optics makes use of reference stars to determine image distortion by the atmosphere and calculate the necessary corrections. Such reference stars, however, need to have a certain brightness – and there is no guarantee that astronomers will find a sufficiently bright star within the same limited field of view as their observation target. That is the rationale behind the ARGOS laser guide star system, which was installed and partially commissioned at the LBT in 2014, with major MPIA involvement. ARGOS will create artificial reference stars on the night sky, which can be used with the two LUCI instruments.

The largest current MPIA instrumentation project by far is the near-infrared beam combiner LINC-NIRVANA (L-N), which was fully integrated in the course of 2014 in preparation for alignment and testing. MPIA is the lead institute in the L-N consortium, which also includes the Italian Observatories (INAF), the Max Planck Institute for Radio Astronomy in Bonn, and the University of Cologne.

The initial aim of the instrument will be to deliver multi-conjugated adaptive optics imagery over a 10.''5 × 10.''5 field of view in the near-infrared regime at wavelengths between 1 and 2.4 µm. An optional future implementation step could provide diffraction-limited imaging with the spatial resolution of a 23m telescope. This would be achieved by coherent combination of light from the two LBT primary mirrors via Fizeau interferometry.

Scientific targets of LINC-NIRVANA range from supernova cosmology, galaxy formation, and extragalactic stellar populations and star formation, to extrasolar planets, stellar multiplicity, the structure of circumstellar disks, and the imaging of solar-system planets and their atmospheres.

As part of the preparations for the final deployment of the complex instrument, the test system Pathfinder was successfully used at the LBT in 2014.

Instrumentation for ESO's VLT/VLTI and for the VISTA telescope

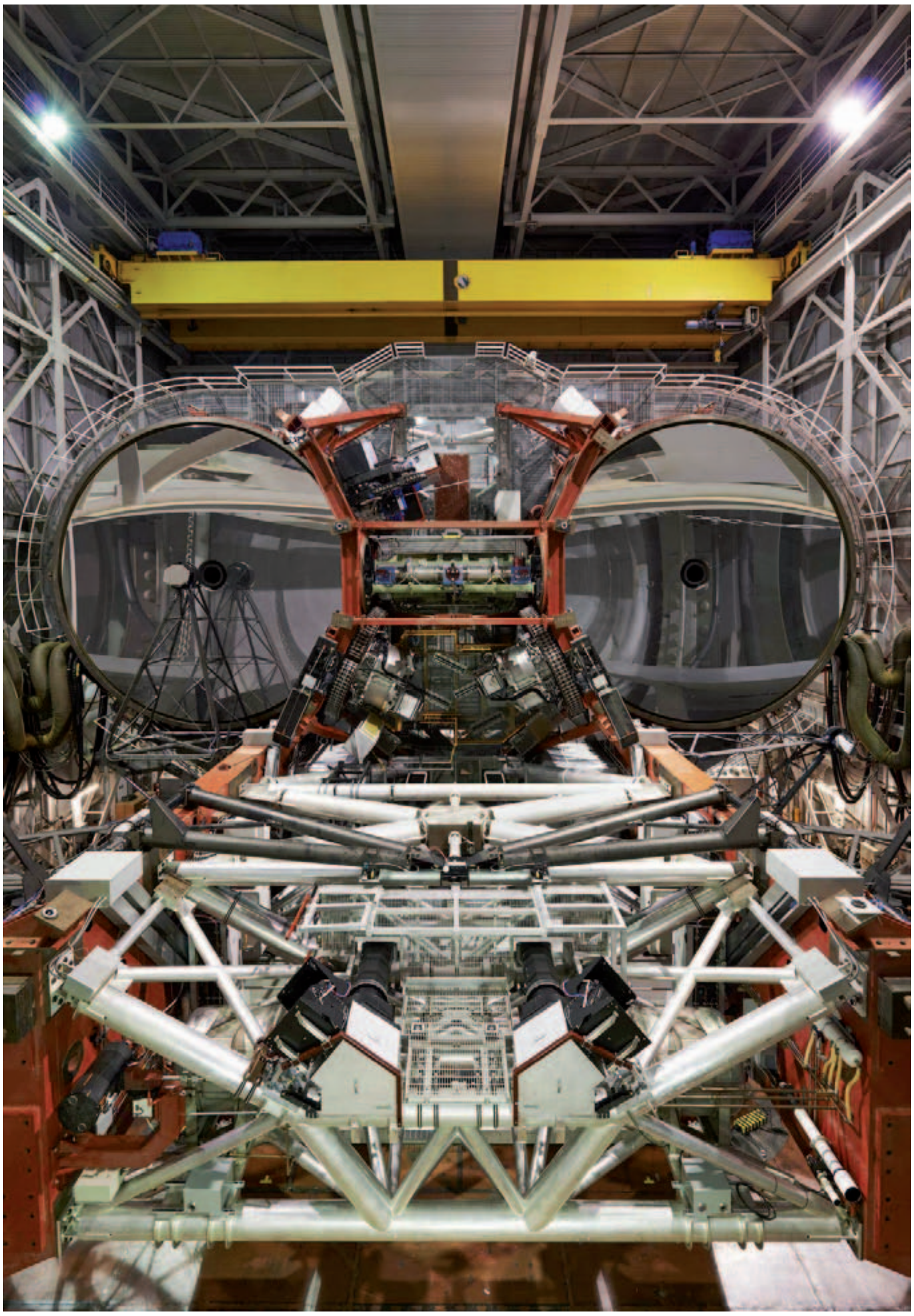
MPIA is participating in the second-generation projects MATISSE and GRAVITY for ESO's Very Large Telescope Interferometer (VLTI) at Paranal Observatory. VLTI combines multiple telescopes of the Very Large Telescope (VLT), namely different combinations of the 8.2 meter unit telescopes and the 1.8 meter auxiliary telescopes.

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 unit telescopes in the mid-infrared for high spatial resolution image reconstruction on angular scales of 10 – 20 milliarcseconds. 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. In July and November 2014, the MPIA delivered its contributions to MATISSE, the two main instrument cryostats, to the point of final instrument integration in Nizza.

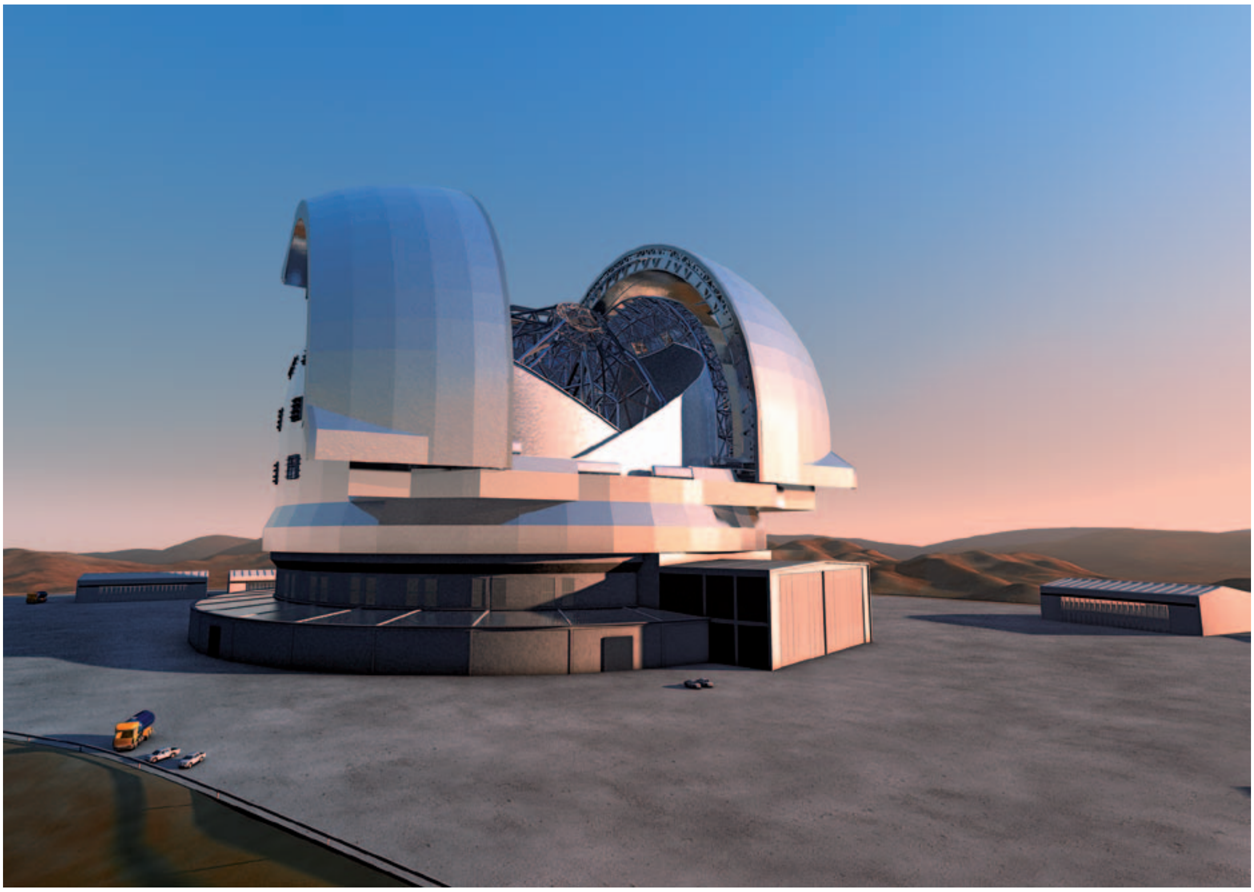
GRAVITY will also combine the light of the four VLT unit telescopes, but in the near-infrared. The GRAVITY consortium is led by the Max Planck Institute for Extraterrestrial Physics in Garching; the partners include MPIA, the observatories in Paris and Grenoble, and the Universities of Cologne and of Lisbon. 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".

Applications include the study of motions close to the massive black hole in the galactic center, the direct

Fig. III.1.1: The Large Binocular Telescope (LBT) on Mount Graham in Arizona (USA). With its two 8.4m mirrors on a single mount, the LBT is currently the largest single telescope in the world with a total light gathering power of a 12m telescope.



Credit: LBTO



Credit: ESO

Fig. III.1.2: Visualization of the European Extremely Large Telescope (E-ELT) on Cerro Armazones in Chile close to ESO's VLT on Paranal. Green light for the construction of the E-ELT was given at the end of 2014.

detection of intermediate mass black holes in the Milky Way galaxy, dynamical mass determinations of extrasolar planets, the origin of protostellar jets, and the imaging of stars and gas in obscured regions of active galactic nuclei (AGN), star forming regions, or protoplanetary disks.

For the instrument SPHERE, a VLT instrument specialized for the imaging of Jupiter-like extrasolar planets, MPIA is a Co-PI institute in a consortium that includes the Laboratoire d'Astrophysique de l'Observatoire in Grenoble, the Laboratoire d'Astrophysique in Marseille, ETH Zürich and the University of Amsterdam. The main challenge for SPHERE is to overcome the huge disparity in brightness between extrasolar planets and their host stars.

To this end, the instrument will use eXtreme Adaptive Optics (XAO), and coronagraphy (that is, a physical obstruction blocking the star's light in the telescope's optical path). It will feature three sub-instruments in the focal plane that are capable of differential imaging, that is, of comparing different images of a planet and its host star, with a view towards distinguishing between the image of the planet and various image artefacts. The three sub-instruments will employ polarimetry in the visual, dual imagery in the near-infrared, and integral field J-band spectroscopy, respectively. In the course of 2014, SPHERE was successfully commissioned, and Science Verification began in December (see Section III.3).

In the course of 2014, MPIA joined the project 4MOST, a multi-object spectrograph for the 4.1m VISTA telescope at ESO's Paranal observatory. The project is led by the Astrophysical Institute Potsdam. 4MOST is currently in its preliminary design phase, with MPIA being responsible for the instrument control electronics. The instrument is supposed to study the origin of the Milky Way and its chemical and kinematic substructure, as well as the evolution of galaxies. To this end it will employ 2400 fibres over a field of view of 4 square degrees, enabling simultaneous spectrography of up to 2400 different objects within the field of view.

Survey instrumentation for Calar Alto (CAHA) and other Observatories

The Panoramic Near-infrared Camera (PANIC) is a wide-field general purpose instrument for the CAHA 2.2m telescope and a joint development of the MPIA and the Instituto de Astrofísica de Andalucía. With four Hawaii2-RG detectors, it provides a field of view of 30' × 30' (corresponding to the apparent size of the full moon in the sky), allowing for surveys of extragalactic, galactic, and solar system objects. PANIC had First Light in November 2014 (cf. section III.3).

CARMENES is a high-resolution near-infrared and optical Échelle Spectrograph currently being built for the CAHA 3.5m telescope by a consortium of German and Spanish institutions. It aims to commence a survey in January 2016 of 300 M-type main-sequence stars in order to find exoplanets in their habitable zones.

The search for transiting extrasolar planets by surveying a large number of nearby stars is the goal of the HATSouth project, a collaboration of MPIA with Princeton University, the Australian National University, and the Pontificia Universidad Catolica de Chile. HATSouth is a network of 24 small-sized automated telescopes located at Las Campanas in Chile, Siding Springs in Australia, and at the H.E.S.S. site in Namibia. MPIA is responsible for the site preparation and operations of the Namibian node.

MPIA scientists also continue to use the ESO/MPG 2.2m telescope at La Silla, namely for special survey work.

The future European Extremely Large Telescope – (E-ELT)

In 2010, an ESO commission led by MPIA, finished the search for the site of the planned 39m E-ELT. The telescope will be located on the Cerro Armazones mountain in Chile's Atacama Desert, in close proximity to ESO's existing Paranal observatory.

In late 2014 the ESO council took the decision to go forward with the construction of the telescope and its first-light instruments. MPIA will participate in two of the instrumentation projects in question: METIS and MICADO.

METIS is a thermal/mid-infrared imager and spectrograph covering a wavelength range between 3 and 19 microns. Adaptive optics will permit the instrument to perform diffraction-limited observations. The instrument's science case includes the conditions in the early solar system, the formation and evolution of protoplanetary disks, studies of the galactic center and of the luminous centers of nearby galaxies, high-redshift active galactic nuclei and high-redshift gamma ray bursts.

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; the successor to the Hubble Space Telescope) by a factor of 6 to 7. It will have a sensitivity down to 29 mag – in visible light, this would include stars more than a billion times fainter than are visible with the naked eye - in the near-infrared bandpasses from I to K.

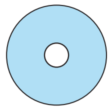
Scientific targets for MICADO include young stellar objects in our galaxy, but also star formation in high-redshift galaxies. High astrometric precision will further advance studies of stellar orbits around the black hole in the galactic center, of the proper motions of globular clusters, the structure, the stellar populations, and the interstellar dust distribution in galaxies with redshifts $z < 1$.

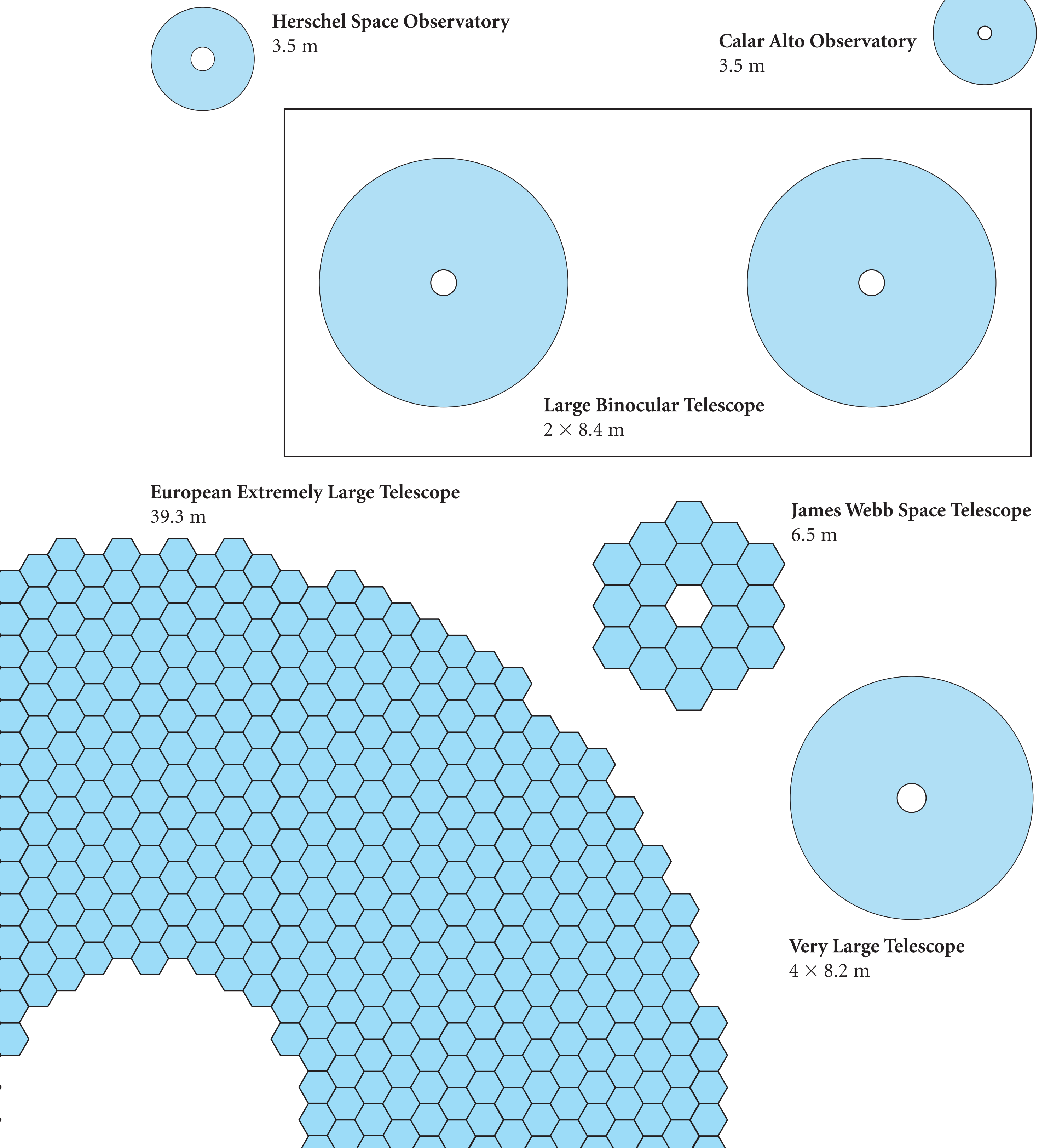
The kick-off for the preliminary design phases of both METIS and MICADO is scheduled for the fall of 2015.

Martin Kürster
for the MPIA Technical Departments

Telescope mirror sizes

Shown here are shape, structure and size of the main mirrors of selected telescopes that are used by MPIA scientists. For a number of these telescopes, MPIA has contributed or is contributing to instrumentation.





III.2 Overview

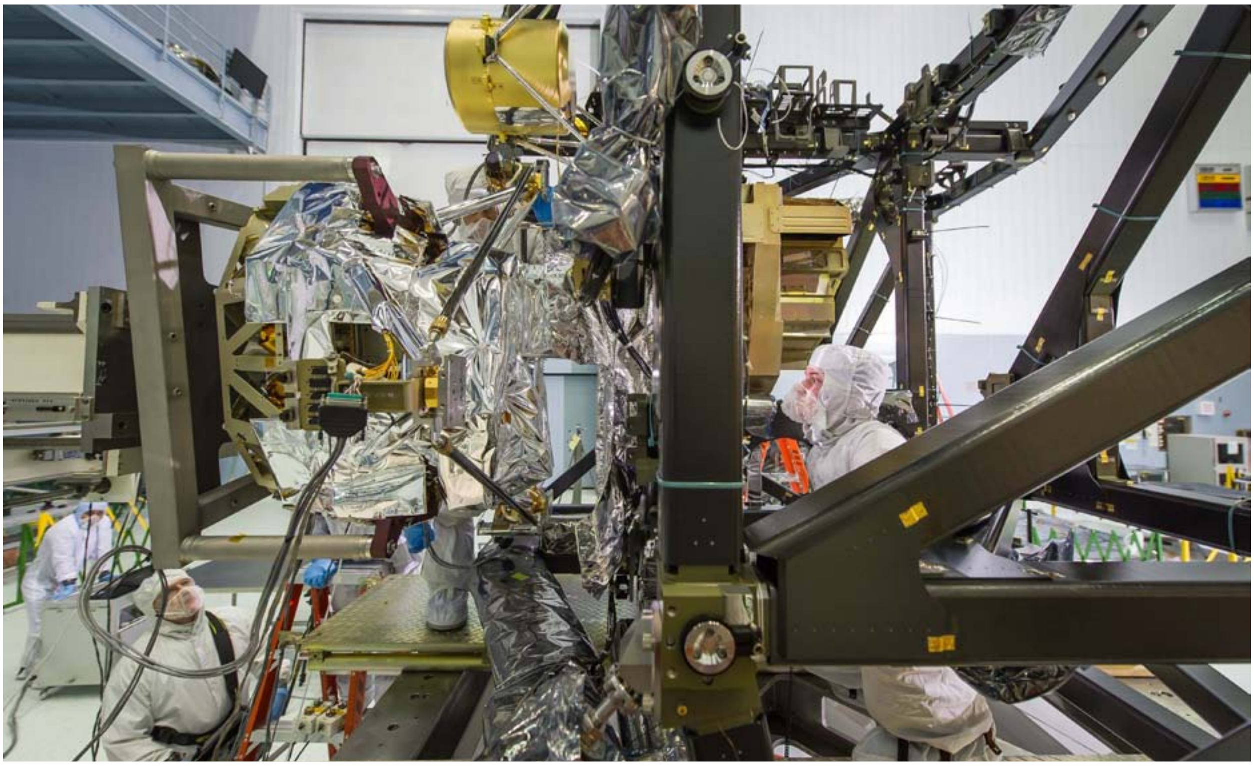
Instrumentation for Space-based Astronomy

James Webb Space Telescope (JWST)

The James Webb Space Telescope (JWST), a space telescope for wavelengths from visible light to the mid-infrared, is on track for launch in autumn 2018 as successor to the Hubble Space Telescope. With its cold 6.5 m primary mirror and four science instruments, JWST will be the premier infrared observatory in space for a decade to come. MPIA is the leading institute in Germany for the development of instrumentation for the JWST. 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 consists of a high-resolution imager and a medium resolution spectrometer and will work in the wavelength range from 5 to 28 micrometers. MPIA has also delivered vital components such as cryogenic motors and high-precision position sensors for the near-infrared multi-object spectrograph NIRSPEC, the second of two JWST science instruments that have mainly been developed in Europe.

Since the delivery of the MIRI instrument to the NASA Goddard Space Flight Center (USA) for integration into the JWST integrated science instrument module (Fig. 1) in May 2012, the instrument has been undergoing a series of rigorous testing campaigns. In 2014, the second full cold test campaign with all four JWST science instruments was successfully completed. For this campaign, MIRI, together with other instruments on the telescope's Integrated Science Instrument Module, were subjected to temperatures of less than -230 degrees Celsius and to vacuum conditions, simulating the environmental conditions under which they will need to operate once deployed into space. The MPIA JWST team significantly contributed to the preparation, conduction and analyses of these tests on site. Currently, the next test campaign planned for end 2015 is under preparation. The MPIA team is also deeply involved in the development for the future data processing pipeline for the MIRI instrument.

Fig. III.2.1: The MIRI Instrument (left) during the integration into the JWST integrated science instruments module (ISIM) in a cleanroom at NASA Goddard Space flight center.



Credit: NASA


Credit: Ö. Detre / MPIA

Fig. III.2.2: Members of the MIRI European consortium and associated scientists during a recent consortium meeting.

This contribution, as well as our participation in the NIRSPEC science team, will provide the astronomers at MPIA with excellent future opportunities for powerful infrared observations. To facilitate preparations of future science observing programs with JWST in the hot-topic field of extrasolar planets, MPIA organized a scientific workshop »Exoplanets with JWST/MIRI« in summer 2014 at Haus der Astronomie, which was attended by many specialists in the field.

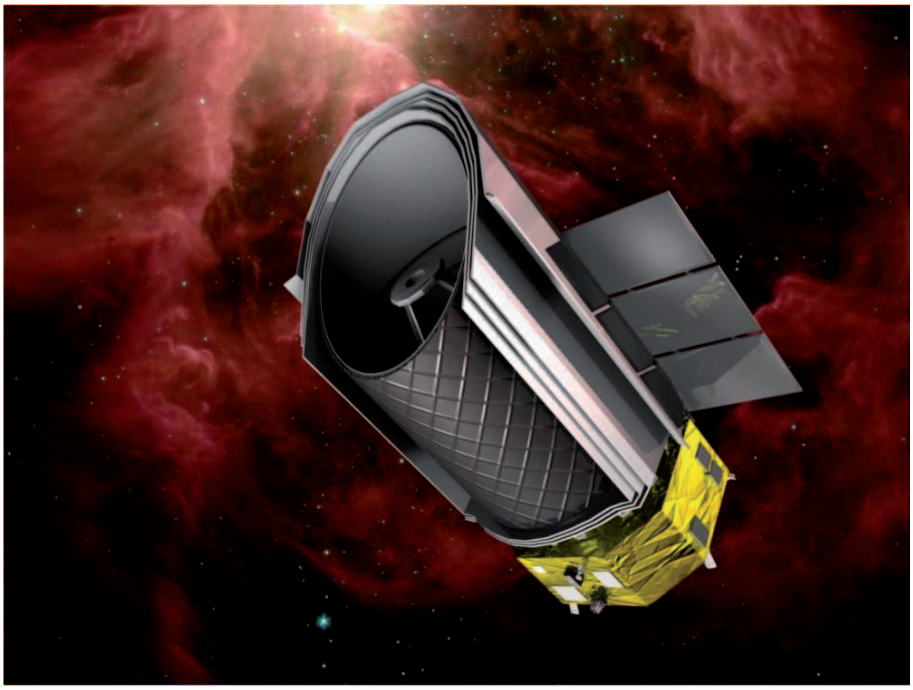
Herschel and SPICA

Europe's far infrared and submillimetre space observatory Herschel was launched in 2009 and provided observational data until April 2013. After the end of the phase, the Herschel project entered its final formal phase, the post-operations phase. During this phase, the aims are to consolidate and archive the exquisite data sets that Herschel delivered during its active four-year mission. Already – and similar to what went on during the operational phase – these excellent data have resulted in numerous publications.

MPIA has been one of the four major partners in the development of the PACS instrument, which enables imaging and spectroscopy in the wavelength range from 60 to 210 μm with unprecedented sensitivity and spatial resolution (the PI institute was the Max Planck Institute for Extraterrestrial Physics in Garching). MPIA was responsible for delivering the PACS focal plane chopper (a device allowing frequent comparisons between the object under study and the celestial background) and for characterizing the spectrometer cameras and their -270°C readout electronics (which is a necessary step to understand the data they provide).

The institute also coordinated a large number of tasks for the calibration of the instrument and was 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, with the help of 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 also designed a corresponding calibration plan for Herschel's routine phase and ensured the optimum inflight setup of the Ge:Ga spectrometer detector arrays, following a procedure developed in MPIAs space laboratory.

The unprecedented observations from the Herschel mission are likely to remain reference data for far-infrared observations for years to come. For this reason, considerable effort is still being put into improving data reduction techniques and reduction pipeline algorithms: Astronomers are unlikely to obtain new far-infrared data in the foreseeable future, hence have great interest in making the most of the existing data.



Credit: ESA

Fig. III.2.3: Conceptual design of the SPICA far-infrared observatory.

As a possible successor to Herschel, the Space Infrared Telescope for Cosmology and Astrophysics SPICA (Fig. III.2.3) is currently under study as one of the candidate astronomy missions of ESA's Cosmic Vision space science program. The mission is foreseen to feature a cold ~3m telescope, providing a sensitivity advantage of up to two orders of magnitude over Herschel, mostly for spectroscopic observations. Under the current plan, SPICA development will led by the Japanese Space Agency Jaxa with a potential launch date in the year 2026. Europe has proposed to participate with the far infrared instrument SAFARI, the telescope mirror, and support for the ground segment. MPIA is contributing to the SAFARI instrument (PI: P. Roelfsema, SRON), more concretely to the testing of the cryogenic detector and the definition and design of the filter wheel mechanism.

Euclid

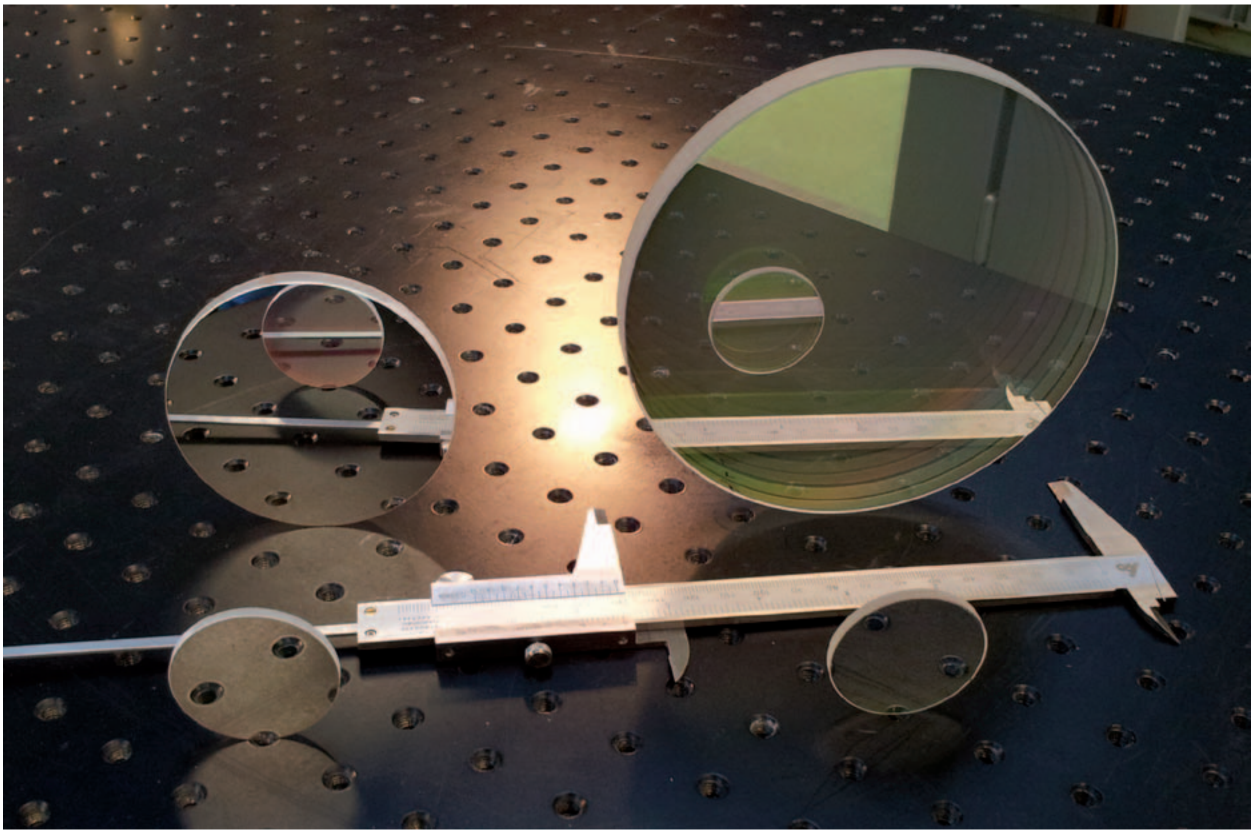
The nature of dark matter and that of dark energy are two of the key open questions in contemporary cosmology: Dark matter does not interact with light or other radiation, yet makes its gravitational influence felt in galaxies, galaxy clusters, and in the expansion of the universe as a whole. Dark energy was introduced to explain the unexpected discovery, published in 1999 and earning its discoverers the 2011 Nobel prize in physics, that cosmic expansion is not slowing down, but accelerating.

ESA's dark energy mission Euclid is set to tackle these open questions by mapping the geometry of the »dark universe«. The mission, which is on track for a 2020 launch, will utilize high-fidelity imaging and spectroscopy in the visual and near-infrared wavelength ranges to map extragalactic objects within 15,000 square degrees of the sky. Its goal is to measure the evolution of cosmic expansion and the distribution of dark matter across cosmic time, from a time 10 billion years in the past (redshift $z = 2$) to today.

Euclid will carry two instruments. The first is VIS, a visible wavelength range imager for high spatial resolution mapping of galaxy structures. It will be used to create a three-dimensional map of weak gravitational lensing across the universe – tiny, statistical effects caused by the deflection of light by mass in the universe, giving information about large-scale mass distribution.

The second instrument is NISP, the Near-Infrared Spectrometer and Photometer whose development is led by the Laboratoire d'Astrophysique de Marseille (LAM). NISP will provide spectroscopic distance measurements of three-dimensional clustering properties of 50 million galaxies. It will also provide the infrared photometry component for so called photometric redshift distances for one billion galaxies.

MPIA contributes to programmatic work in Euclid, specifically by overseeing all calibration strategies, and also to the planning and construction of the NISP instrument. The Euclid group at MPIA is responsible for translating the higher-level requirements from the mission to hardware performance requirements, and to simulate the expected overall performance during the construction of the instrument. In addition, a major MPIA contribution will be hardware components for NISP, namely the near-infrared filters and the calibration light source, funded by the German national aerospace agency DLR.

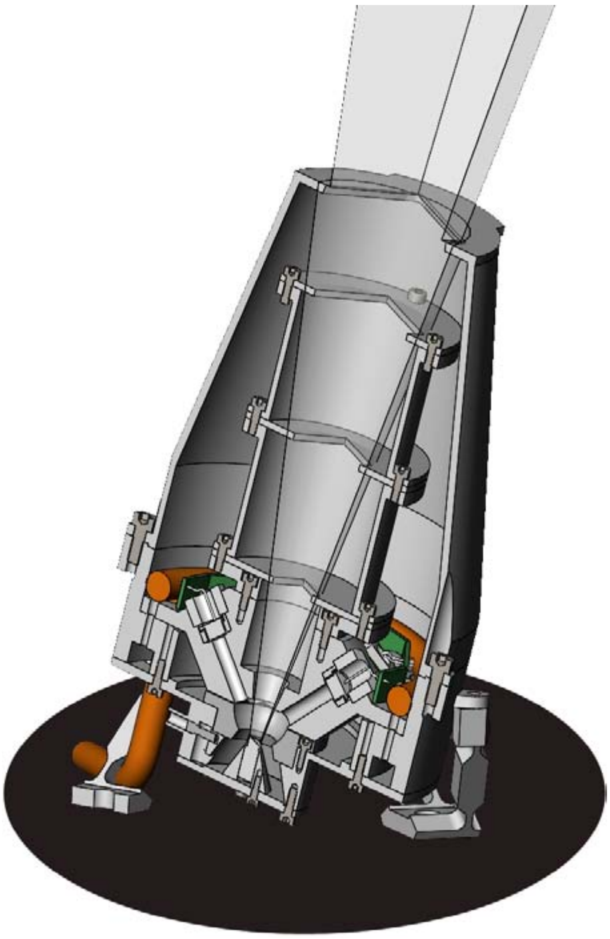


Credit: F. Hormuth / MPIA

Fig. III.2.4: Coated NISP test filters from 40 mm to 140 mm in diameter.

In 2014, all hardware components successfully passed the Preliminary Design Review, one of two major hardware-milestones before the actual manufacturing of flight hardware commences. Both the filters and the calibration source demonstrated an impressively advanced level of development, an excellent foundation for work towards the next step, the Critical Design Review, which is scheduled for late 2015. Once all components and the overall instrument have passed this review, production will start for those components that will actually be used during the flight. The delivery of both the filters and the calibration source to the other project partners is slated for early 2017.

In the past year, concept studies for the filters carried out with industry partners have resulted in test specimens, coated with a complex 200-strong stack of interference filter layers, of a representative NISP bandpass. The largest sample, with a diameter of 140 mm, approximates the size eventually needed for NISP. This should be compared to the 77 mm diameter filters in JWST NIRcam, which will be the largest (astronomical) infra-



Credit: von Hoerner & Sulger / Schwetzingen; F. Hormuth / MPIA

Fig. III.2.5: Graphic representation of the NISP calibration source: a simple design for a complex calibration task. The total height of the unit is a mere 25cm, its weight only about 600 grams.

red filters to be flown before Euclid. All test filters, although produced with two different coating mechanisms and for two different bandpasses (Fig. III.2.4), showed a performance well in line with specifications, which is a reassuring basis for the final development and manufacturing in 2015 and 2016.

The NISP calibration source weighs in at a mere 600 g, but forms the core of calibrating NISP detectors in flight (Fig. III.2.5). A novel design based on light-emitting diodes (LEDs) instead of the usually used tungsten filaments allows for better time-stability of light emission. Hence, it can be used not only to calibrate the relative pixel-to-pixel response of the detectors, but also to re-measure the instrument's response as a function of light intensity. This is crucial, since infrared-detectors show a substantial non-linear transfer of input to output, and this would, otherwise, fundamentally limit the accuracy of the photometric data calibration. The novel MPIA approach requires the qualification of LEDs for use in space, which includes exposing them to cryogenic temperatures, vacuum, and a high-radiation environment. This complex work which started in 2014 and will stretch into 2016.

Overall, Euclid at MPIA is well on track towards the final design of the NISP instrument by early 2016, and a completion of the whole instrument in 2018. MPIA's involvement in Euclid will not stop there, but will shift towards contributions to the computing ground segment and, later, to exploitation of the vast and unprecedented dataset.

This will include highly interesting analyses outside the mission's nominal main science goals: With a substantial high spatial-resolution visible imaging dataset (0.1 arcseconds) and deep infrared data (S/N=5 for point sources at 24 magnitude) for over a third of the sky, the possible science applications are vast, ranging from observational studies of galaxy evolution to the discovery and characterization of exoplanets.

Oliver Krause for the IR Space Group
and
Knud Jahnke for the Euclid Group

III.3 Instrumentation and Technology

First Light for SPHERE and for PANIC

Advanced astronomical instruments are developed and constructed by consortia of astronomical institutes, and the best instruments incorporate significant advances in technology. That is why, even after rigorous testing, the moment of »first light«, when the first images or spectra are taken with the instrument attached to its telescope, is an exciting occasion for all concerned. In 2014, two instruments with major MPIA involvement reached this milestone: the exoplanet hunter SPHERE at ESO's Very Large Telescope and the wide-field imager PANIC at the 2.2m telescope at Calar Alto Observatory.

Imaging extrasolar planets with SPHERE

The search for exoplanets – planets orbiting stars other than our sun – and research into their properties, formation and possibly Earth-like nature is among the most exciting challenges of modern astrophysics. However, all but a few of the more than 1000 known exoplanets have only been detected indirectly. Direct images of such planets are rare.

There are several reasons for the scarcity of exoplanet images. One is that the angular distance between an exoplanet and its host star is extremely small, due to such systems' considerable distance from us. Even in our direct cosmic neighbourhood, at a distance of about 30 light-years (about 300 trillion kilometers), a planet with an orbit as large as Earth's orbit around the sun would only be separated from its host star by about a tenth of an arc second. Creating an image in which both star and planet are visible separately corresponds to the challenge of imaging two adjacent Euro coins from a distance of about 40km. To make matters even more difficult, the contrast in brightness between a star and a planet is gigantic, amounting to some millions. In our simile, this would amount to replacing one of the coins by a floodlight, the other by a firefly.

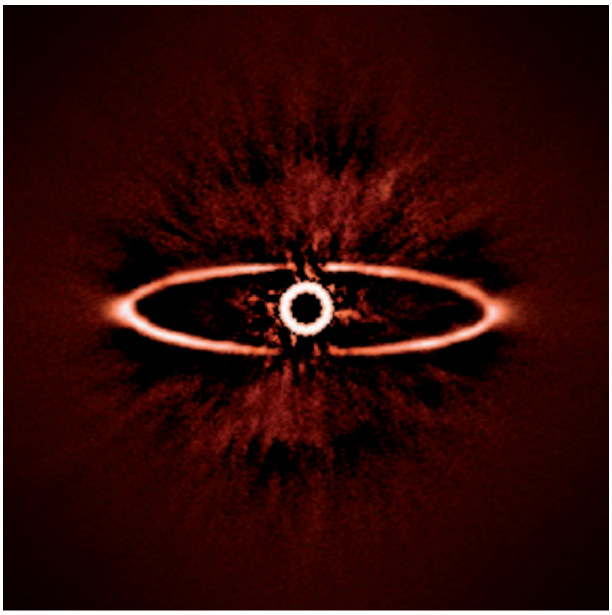
The instrument SPHERE (the acronym stands for Spectro-Polarimetric High-contrast Exoplanet REsearch) is an extraordinary high-tech instrument designed to produce images under precisely those extremely difficult conditions. Its main targets are exoplanets as well as circumstellar disks of gas and dust in which new planetary systems are forming.

In early June 2014, SPHERE saw first light at the Very Large Telescope (VLT) of the European Southern Observatory (ESO) in Chile, for test observations using the different modes of observation available. Right away, SPHERE produced an impressive image of a dust ring around the nearby star HR 4796A. The unusual clarity of the image demonstrates SPHERE's powers of suppressing the light emitted by the star itself, which would be in the center of the image. Given the instrument's complex technology, with numerous interlocking hardware and software components designed to remove instrumental artifacts with great precision, it is remarkable to achieve such impressive performance without a long adjustment process.

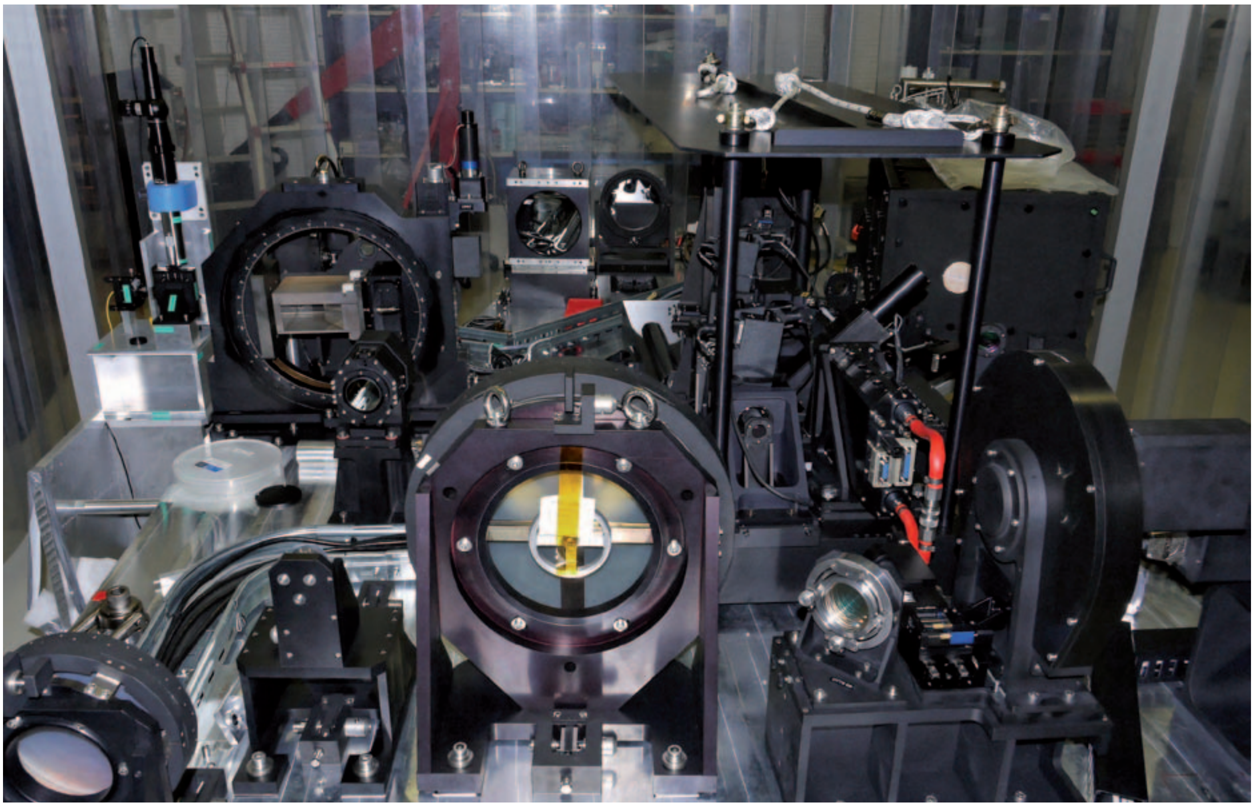
The instrument's three main components are a polarimeter, a camera, and a field spectrograph, all designed for the visual to infrared range of the electromagnetic spectrum. The instrument combines several different techniques for achieving the highest possible contrast for its images of exoplanets and dust disks. In order to separate faint objects from the glare of nearby stars, an »extreme adaptive optics« system is deployed, which can correct image degradation due to atmospheric turbulences in the Earth's atmosphere (»twinkling stars«) in real time. An ensemble of coronagraphs mechanically blocks light from the star along the telescope's optical pathway.

Last but not least, the telescope uses what is known as differential imaging to separate particularly dim real structures (such as an exoplanet) from the effects of stray

Fig. III.3.1: This infrared image of a dust ring around the nearby star HR 4796A in the Southern constellarion of Centaurus is one of the first images ever taken with the SPHERE instrument. It demonstrates SPHERE's capability to suppress the light of the star in the center of the image.



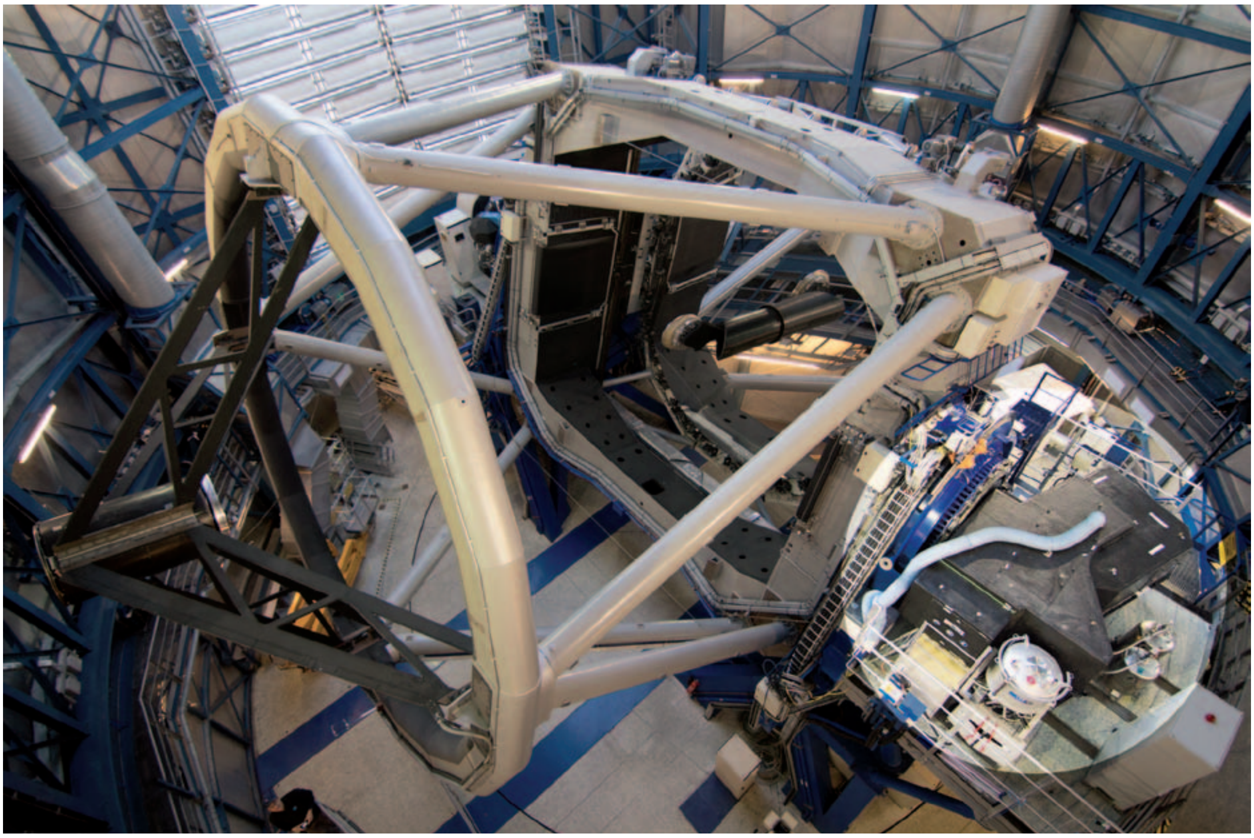
Credit: ESO / J.-L. Beuzit et al. / SPHERE Consortium



Credit: SPHERE Project/ESO / J.-L. Beuzit

Fig. III.3.2: The complex optics of the SPHERE instrument shortly before the instrument was shipped to Chile in December 2013.

Fig. III.3.3: The SPHERE instrument (see highlighted circular area) newly installed at the VLT unit telescope 3 in spring 2014.



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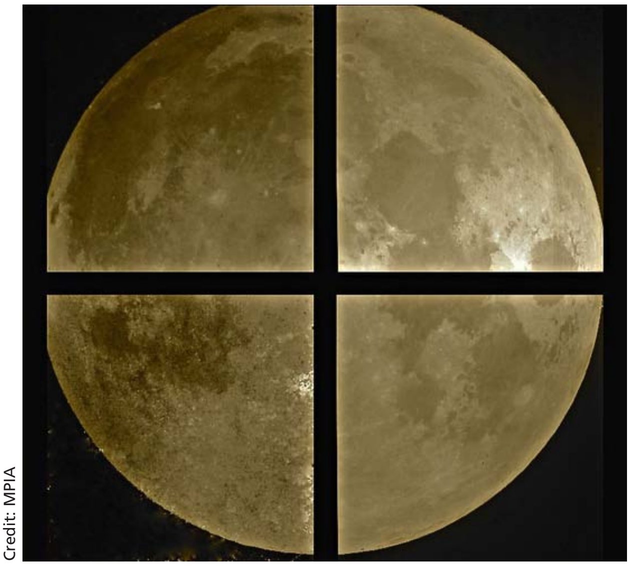


Fig. III.3.4: The full moon on November 6 at 22:06 UT in the near-infrared. Although the Moon is not a typical target for a large telescope, this image illustrates PANIC's enormous field of view, particularly when compared to other infrared cameras. The moon was only three days past its closest possible distance to earth and it therefore over fills the mosaic (whose four detectors are separated by 75 arc seconds, with the gaps visible as black stripes). This 1.6 second exposure was taken through a filter with only 1% transmission centered at 2.118 microns. Inspite of the narrow filter and short exposure time, the astronomers had to use the telescope dome to block part of the moonlight. The raw image is only slightly processed to compensate position-dependent detector sensitivity (different brightness of the quadrants) and bad pixels.

Fig. III.3.5: Spiral galaxy Messier 74 (NGC 628) in the constellation Pisces at a distance of about 35 million light-years. The PANIC near infrared image was also taken on November 6, 2014 (23:55 UT). Given its large apparent size, a one shot full portrait of this galaxy is more typically a target for much smaller telescopes. However, M74 fits comfortably in one of the four PANIC detectors. Two shots of only 30 seconds exposure time were combined. The intensity of the typical infrared sky background exceeds even the bright galactic nucleus by a factor of 30. A relatively simple correction (sky subtraction) is achieved by a measurement on the same detector while the object is recorded alternately on a different detector. Between the exposures the telescope's line of sight is slightly moved.

light within the instrument. This works as follows: If you take numerous separate images during a single night, with the star firmly fixed in the center of the image, then light artifacts due to the instrument will appear as an unchanging pattern. If, on the other hand, the region of the sky under observation rotates over the course of the night relative to the image plane, then so will the orientation of the planet in the image. By combining and comparing the various images, the non-rotating artifacts and the rotating planetary image can be separated. Additional differential imaging techniques separate planetary from residual stellar contributions to the image by the spectral or polarimetric properties of the respective structures in the image.

SPHERE could revolutionize research on exoplanets and circumstellar disks. In order to understand the formation, dynamics and evolution of planetary systems, it is important to understand the distances of the planets from their host stars and the properties of their orbits. Model calculations make definite prediction for systematic effects, which are amenable to observational tests. For example, models predict certain preferred distances for Jupiter-like gas planets. SPHERE can discover and characterize those gas giants, following their changing positions via imaging.

SPHERE has been installed at VLT unit telescope 3 »Melipal« since May 2014, after having been shipped from Europe to Chile in December 2013, on having passed final review and certification. After additional exhaustive testing, SPHERE was made available to the wider astronomical community in late 2014.

The SPHERE consortium consists of twelve major European astronomical institutes and additional partners. The lead institute (PI institute) is the Institut de Planétologie et d'Astrophysique de Grenoble, in France, with Jean-Luc Beuzit as Principal Investigator (PI). MPIA's Markus Feldt is Co-PI.

Wide-field observations: PANIC at Calar Alto Observatory

After eight years of development, the near-infrared wide-field camera PANIC entered operations during the full moon night November 6/7 2014 at the Calar Alto 2.2m telescope. The first test images with PANIC have already demonstrated the instrument's exceptional performance.

PANIC (PAnoramic Near-Infrared Camera) is a joint project of the Max Planck Institute for Astronomy (MPIA) in Heidelberg and the Instituto de Astrofísica de Andalucía (IAA) Granada. The project management is shared between Matilde Fernandez (IAA) and Klaus Meisenheimer in Heidelberg (replacing Josef Fried who, until his retirement, was the MPIA project manager). While IAA is mainly responsible for the optical design, optical adjustment and the observation- and pipeline software, MPIA takes care of the mechanics (cryostat, filter wheels, etc.), the readout electronics and the motor controller.

The new instrument has several unusual features. While the development of highly sensitive electronic CCD cameras has revolutionized astronomical observations in visible light since the 1980s (with many elements of this technology now used in everyday cameras), the development of similar cameras for the infrared range of electromagnetic radiation proved considerably more difficult – particularly under conditions requiring both large fields of view and good spatial resolution. PANIC consists of four detectors (with 2048 × 2048 pixels each), forming a square mosaic. When mounted at the 2.2m telescope, PANIC captures a field of view of ½ degree in diameter at a resolution of 0.45 arcsec per pixel. Thus, the PANIC field covers roughly the average apparent diameter of the full moon and allows for both the detailed investigation of nearby extended objects and the observation of large samples of distant objects (for example, surveys of distant clusters of galaxies).

Infrared observations are key to understanding many astronomical phenomena since the radiation from young stars and planetary systems penetrates their surrounding dust clouds only at longer wavelengths. Furthermore, the observation of distant galaxies is much easier, since important parts of their light spectrum are shifted into the infrared due to the expansion of the universe.

Markus Feldt and Thomas Henning
for the SPHERE Consortium,

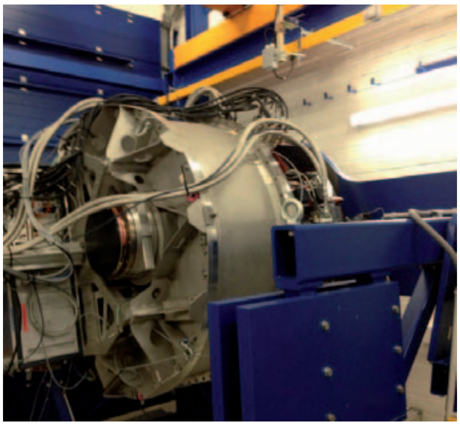
and

Klaus Meisenheimer
for the PANIC Consortium

III.4 Instrumentation at MPIA

Overview of Current Projects

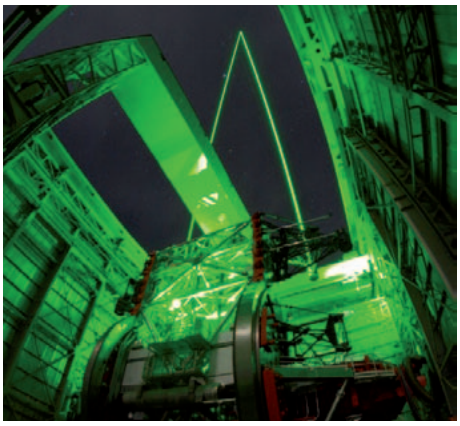
Astronomical instruments have different strengths and specializations. Here, we list **current MPIA instrumentation projects**. Almost all of the instruments are cameras for producing astronomical images, spectrographs for analyzing the component colors of light, or combinations thereof. The only exception is Argos, which supports other instruments to take sharp images by projecting an artificial laser star into the sky.



LUCI 1 + 2

LBT NIR spectroscopic Utility with Camera and Integral-Field Unit

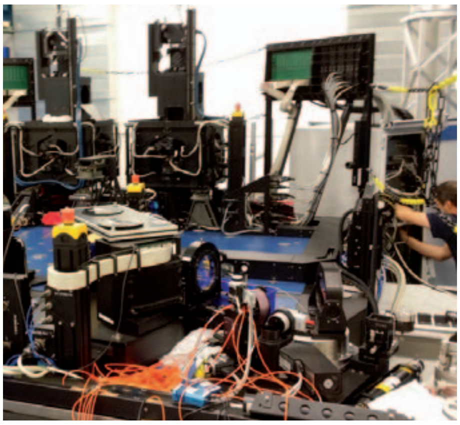
Telescope	Large Binocular Telescope, Mt. Graham
Wavelength range	Near-infrared, 0.85 – 2.5 µm
Targets	Galaxy clusters and star clusters
Resolution	30 – 90 mas (wavelength-dependent with AO)
Special features	can examine multiple objects at once
MPIA contribution	Electronics, software, detectors, cryogenics, integration facility
Status	Operational, upgrades to be completed in 2015



ARGOS

Advanced Rayleigh guided Ground layer adaptive Optics System

Telescope	Large Binocular Telescope, Mt. Graham
Wavelength range	-
Targets	-
Resolution	-
Special features	Can examine multiple objects at once
MPIA contribution	Testing, control software/motor control, calibration, alignment
Status	Commissioning started 5/2014, completion planned for 2016



LINC-NIRVANA

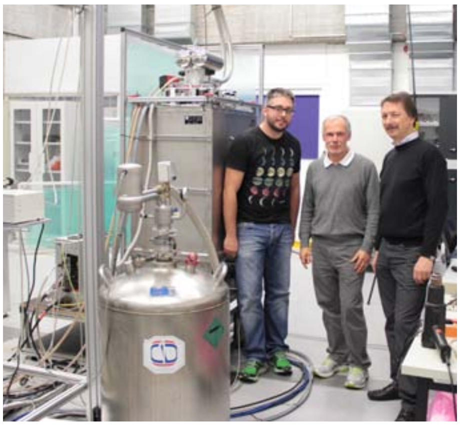
**LBT INterferometric Camera –
Near-InfraRed Visual Adaptive interferometer for Astronomy**

Telescope	Large Binocular Telescope, Mt. Graham
Wavelength range	Near-infrared, 1.1 – 2.4 µm
Targets	Star clusters, black holes, protoplanetary disks
Resolution	30 – 90 mas (wavelength-dependent); interferometric: 10 – 30 mas
Special features	Particularly wide-fileld adaptive optics
MPIA contribution	PI institute, project lead; optics, electronics, software
Status	To be shipped in fall 2015, installation at LBT planned for 2016

SPHERE

Spectroscopic and Polarimetric High-contrast Exoplanet REsearch

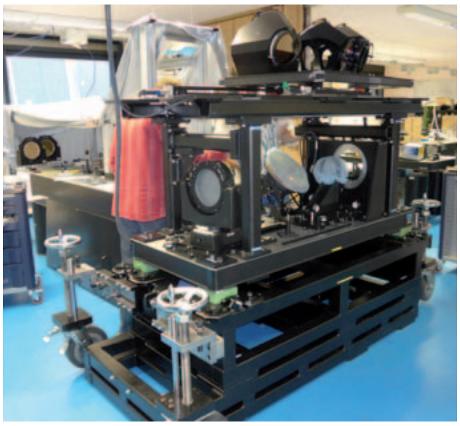
Telescope	Very Large Telescope, Paranal, Chile
Wavelength range	Near-infrared, 0.5–2.32µm depending on instrument mode
Targets	Imaging extrasolar planets and their birthplaces
Resolution	14–58mas depending on wavelength and instrument mode
Special features	Coronagraph (masking the host star), eXtreme Adaptive Optics
MPIA contribution	Co-PI institute, data reduction software
Status	Commissioning 10/2014, science verification phase 12/2014



MATISSE

Multi AperTure mid-Infrared SpectroScopic Experiment

Telescope	Very Large Telescope, Paranal, Chile
Wavelength range	Mid-infrared (3 – 25 µm = L, M, N bands)
Targets	Active galactic nuclei, protoplanetary disks, hot/evolved stars
Resolution	3 – 26 mas depending on wavelength and telescope baselines
Special features	Image reconstruction from interferometric data
MPIA contribution	Integration cryostats with cold optics/detectors, electronics/tests
Status	start of integration at VLT August 2016



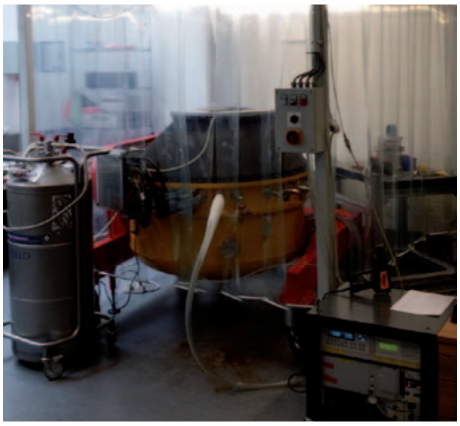
GRAVITY

Telescope	Very Large Telescope, Paranal, Chile
Wavelength range	Near-infrared, 2.2 µm
Targets	Milky Way black hole, planets, brown dwarfs, disks/jets, AGN
Resolution	4 mas for imaging
Special features	High-precision narrow-angle astrometry down to 10mas
MPIA contribution	Four wavefront sensors for the AO system
Status	Four AO units being built at MPIA

Each camera or spectrograph has a characteristic **wavelength range**, describing the kind of electromagnetic radiation it can receive. Most MPIA instruments work in visible light, with radiation we can see with our own eyes, or in the infrared regions of the spectrum: in the near-infrared (adjacent to the region of visible light, able to see through clouds of dust), the mid-infrared (where dust heated by stars radiates, as in protoplanetary disks) or the far-infrared (radiated by the coldest known objects in the cosmos, or the most distant).

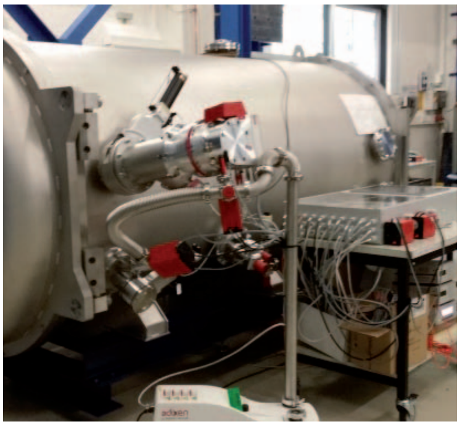
Astronomical objects are extremely distant, making it difficult to discern any details. The **resolution** is a measure of the level of detail that can be discerned using a particular instrument. Resolution is given as an angle on the sky: a resolution of 0.1 arc second means that, say, an astronomical camera can distinguish two small objects that are 0.1 arc seconds (less than 0.00003 of a degree) apart on the sky. Resolution is typically given in arc seconds (1 arc second = 1/3600 of a degree) or even milli-arc seconds, mas (1 mas = 1/1000 arc second).

Specific instruments have characteristic **special** features or properties. A particularly wide field of view, for instance, allowing for survey images of larger regions of the sky. Adaptive optics to counter-act atmospheric dis-



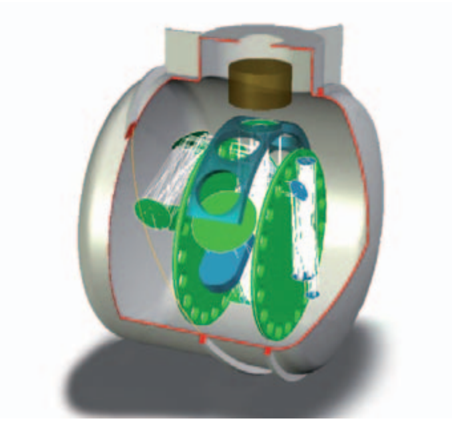
PANIC
PAnoramic Near-Infrared Camera

Telescope	2.2m telescope, Calar Alto
Wavelength range	Near-infrared, 0.9 – 2.15 µm
Targets	GRBs, distances, star formation, ejected brown dwarfs, mapping
Resolution	Seeing-limited
Special features	Large field of view – size of the full moon
MPIA contribution	PI institute, cryo-mechanics, detector array, optical components
Status	First light 11/2014, open use starting 4/2015



CARMENES
Calar Alto High-Resolution Search for M Dwarfs with Exoearths with Near-infrared and Optical

Telescope	3.5 m Telescope, Calar Alto
Wavelength range	Near-infrared and visible light, 0.5 – 1.7 µm
Targets	Planets around 300 M dwarf stars including Earth-like planets
Resolution	High spectral resolving power of 82,000 (spatial resolution n/a)
Special features	Two high-precision spectrographs for radial velocity measurements
MPIA contribution	NIR detector/cryostat, electronics, software, integration facility
Status	NIR detector cryostat delivered to Granada in 04/2015



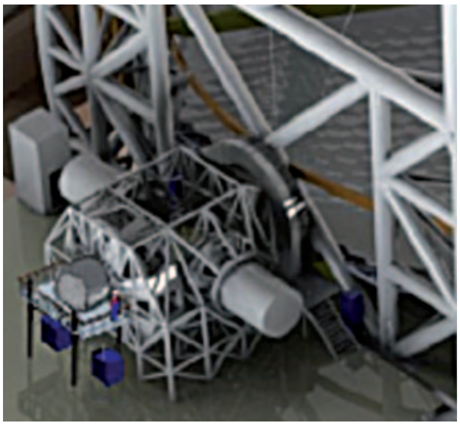
MICADO
Multi-AO Imaging Camera for Deep Observations

Telescope	European Extremely Large Telescope
Wavelength range	Near-infrared, 1.1 – 2.5 µm
Targets	Stellar motions in galaxies, dwarf galaxies, first supernovae
Resolution	6 – 13 milliarcseconds depending on wavelength
Special features	High sensitivity, precise astronometry
MPIA contribution	Cold filter wheel, astrometric calibration
Status	Planning and preparation phase

turbances. The ability to determine the orientation in which an electromagnetic wave is oscillating (polarimetry), or to block out light from part of the field of view (coronagraphy). Or the use of interferometry to combine the light from several telescopes, allowing them a level of detail otherwise accessible only to a much larger telescope.

Each instrument is designed with specific astronomical **targets** in mind. For MPIA researchers, these targets center around our central research themes of planet and star formation on the one hand, galaxies and cosmologies on the other. That is why typical targets are star formation regions, which are hidden behind clouds of dust that can be pierced using infrared radiation, or very distant galaxies whose light has been shifted by cosmic expansion, again necessitating infrared observations.

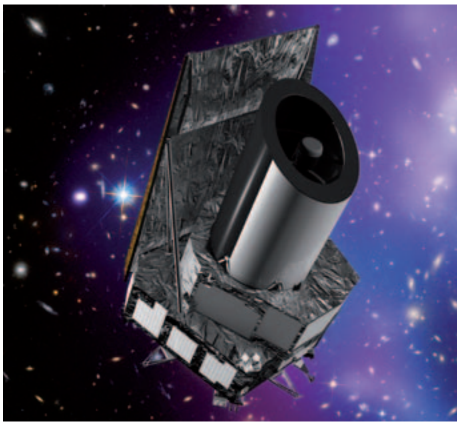
For each instrument, we also list its **current status**. Design and construction of an instrument encompass several phases. In the beginning, there is a phase of intensive planning, which often includes tests of the necessary technology. The construction phase is followed by integration, in which the separate components are combined



METIS

Mid-infrared E-ELT Imager and Spectrograph

Telescope	European Extremely Large Telescope
Wavelength range	Mid-infrared (3 – 9 µm = L/M, N, Q bands)
Targets	Disks, exoplanets, supermassive black holes, high-z galaxies
Resolution	16 – 74 mas depending on wavelength
Special features	Can do coronagraphy and polarimetry
MPIA contribution	Imager and single-conjugate adaptive optics
Status	Planning and preparation phase



EUCLID

Telescope	Euclid denotes the whole space telescope
Wavelength range	Visible light, 0.5 – 0.9 µm, and infrared light, 0.965 – 2.0µm
Targets	Tracing cosmic large-scale structure and cosmic acceleration
Resolution	86 – 344 milliarcseconds depending on wavelength
Special features	Galaxy morphology, IR photometric redshifts and spectroscopy
MPIA contribution	Part of infrared detector calibration unit, large
Status	Planning and construction phase

to form the instrument as a whole, the commissioning phase in which the instrument is installed at the telescope, first light as the first images/spectra are taken, science verification as the new instrument is tested on various astronomical targets, and finally an operations phase for scientific operations.

Fig. III.4.1: At its December 3, 2014 meeting, the ESO Council approved a two-phase plan for the construction of the European Extremely Large Telescope (E-ELT). Center right: MPIA director and council member Thomas Henning.

Credit: NASA

III.5 Technical departments Highlight

Technical Departments Highlight: All-new Machine Park and Partial Overhaul for the Precision Engineering Workshop

The precision engineering workshop plays a key role whenever MPIA's contribution to astronomical instruments includes mechanical components that need to be constructed, tested, and for which prototypes need to be manufactured. Specific expertise includes moving mechanical components for space telescopes, which demand not only extremely precise adherence to measurements, but need to function in vastly different thermal environments – from the heat of ESA's Kourou space port to the cold of outer space.

New machinery

In the past years, budget considerations prohibited larger amounts of money being spent on replacing old machinery with new in the precision engineering workshop. While the workshop has managed to keep its machinery, dating from the 1970s and early 1980s, fully functional, replacement became a matter of ever greater urgency over the last years. One reason was the dwindling supply of spare parts, another an increase in maintenance and repair costs, leading to longer and longer downtime periods. Also, modern machinery is subject to much stricter safety standards.

A special call by the MPG offering funds for the renovation of old equipment provided a good opportunity for MPIA to modernize the precision engineering machinery. Seven different machines and a variety of accessories were replaced by their 2014 building-date counterparts. Included are one large and two smaller metalworking lathes, a sandblaster, a circular hand saw for cutting metal, a controllable heat treatment and, last but not least, and slated for arrival in 2015, a large CNC milling machine.

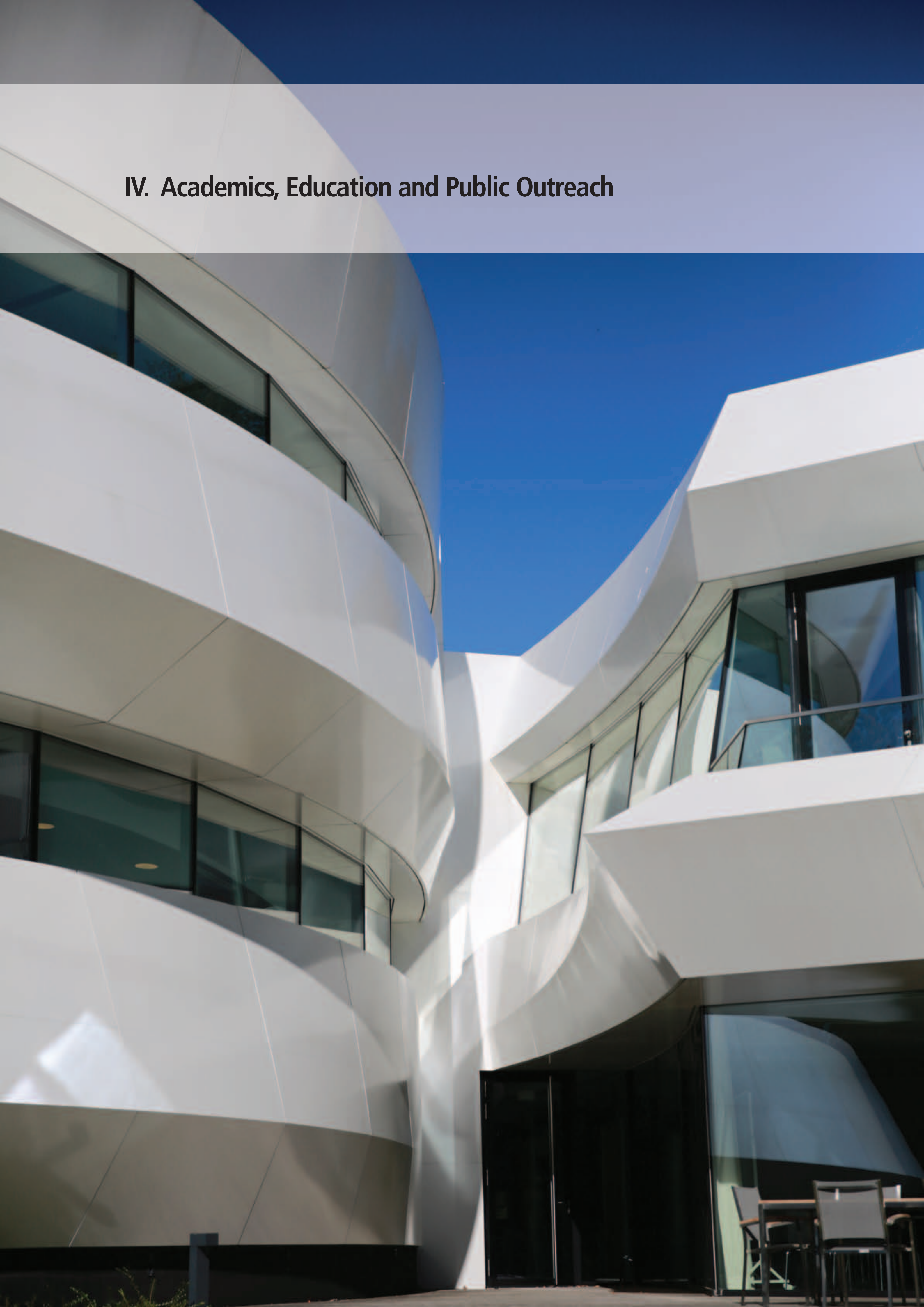
Renovation

The premises of the precision engineering workshop also underwent extensive renovation. The floor was replaced completely, and new data and electrical conduits installed throughout, supplemented by new lamps, work benches and cupboards. The ceiling was replaced in parts; all in all, completion of the renovation is slated for 2015, with the details pending a decision on a proposed annex to the main workshop area.

Fig. III.5.1: The precision engineering workshop after renovation. Two of the new high-precision lathes can be seen in the background.

Credit: MPIA

IV. Academics, Education and Public Outreach



IV.1 Academics, Education and Public Outreach

Academics

As a research institute, MPIA takes seriously its responsibility for fostering future generations of scientists. Our commitment begins at the undergraduate level. Both the directors and the research group leaders are involved in teaching at Heidelberg University. For instance, this year MPIA scientists were involved in teaching the basic courses "Introduction to Astronomy and Astrophysics I" (H. Beuther, C. Fendt) and part II of the same course (K. Jahnke, H.-W. Rix), holding tutorials for the basic experimental physics courses as well as offering numerous tutorials, seminars and more advanced courses on more specialized astronomical subjects.

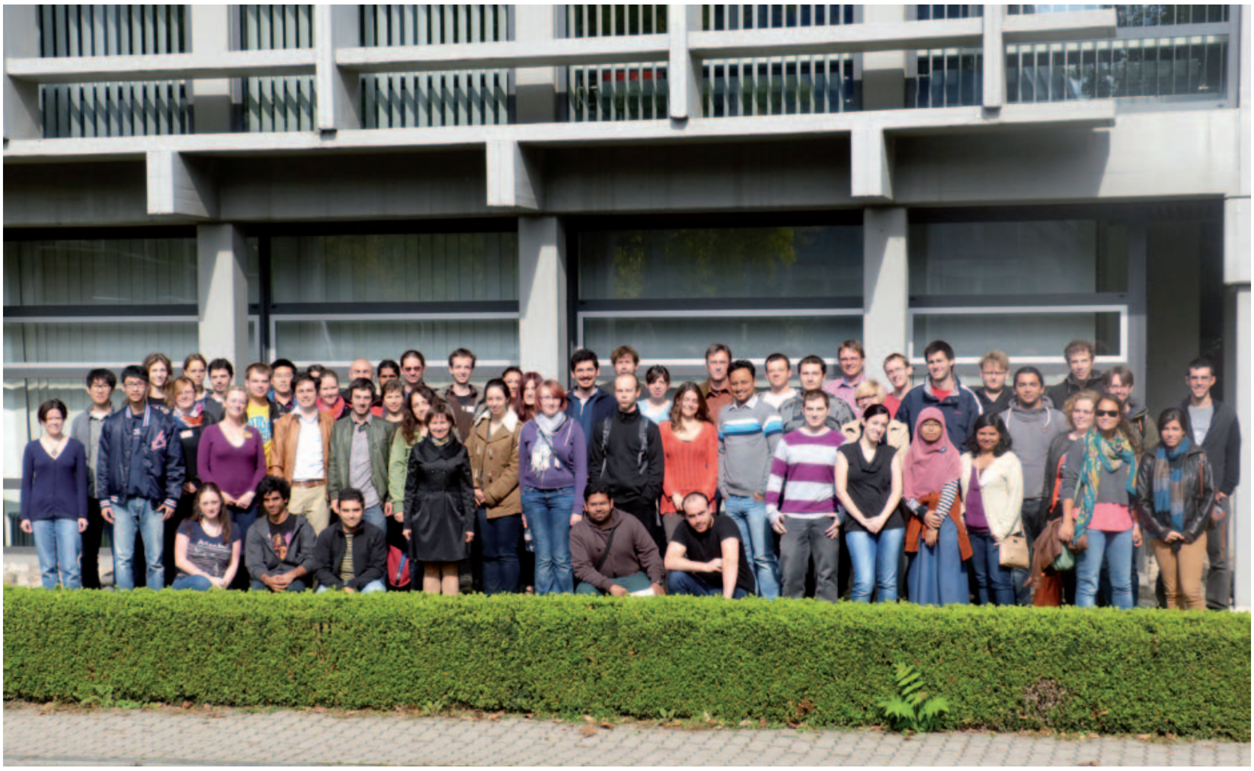
MPIA also offers bachelor and masters students from Heidelberg University or from other universities the opportunity to conduct research for their theses at the institute. For students intent on gaining research experience, there is a successful international summer internship program (coordinator: B. Goldman).

Training PhD students is one of the focus area of academics at MPIA. More generally, International Max Planck Research Schools (IMPRS) are a key part of the Max Planck Society's efforts to promote PhD students. MPIA is one of the partners of the International Max Planck Research School for Astronomy & Cosmic Physics at the University of Heidelberg (IMPRS-HD), a graduate School offering a doctoral program in astrophysics. IMPRS-HD, which currently hosts about 90 PhD students, is coordinated by MPIA's Christian Fendt.

IMPRS-HD is international - among the 202 applicants for 20 new IMPRS places in 2014, 36 were from Germany, 54 from other European countries, 24 from the Americas, 65 from Asia, 17 from the Middle East and 5 from Africa.

The program includes not only a central application and admission process that pairs candidates with suitable advisors, but also offers regular thesis committee meetings to supervise student work and education and assist the student with charting their academic course. It also has a mandatory astronomy curriculum, ensuring that graduates have a well-rounded astronomical education when they finish their degrees. IMPRS fellows

Fig. IV.1.1: Group picture of the 2014 IMPRS Summer School on Frontiers of Stellar Structure and Evolution.



Credit: IMPRS-HD

Fig. IV.1.2: Students working out exercises at the 2014 IMPRS Summer School in September 2014.

regularly meet, present their work and discuss ideas in the weekly IMPRS seminars. Yearly workshop retreats provide an even more intensive exchange between the IMPRS fellows, complemented by social events for the students.

Another feature of IMPRS-HD is its yearly international summer school. In 2014, the 9th Heidelberg Summer School, whose scientific program was organized by Norbert Christlieb and Hans Ludwig (both ZAH), brought together 56 international participants and 5 lecturers from Germany, Australia, the UK and Denmark for an in-depth look at the Frontiers of Stellar Structure and Evolution

Christian Fendt

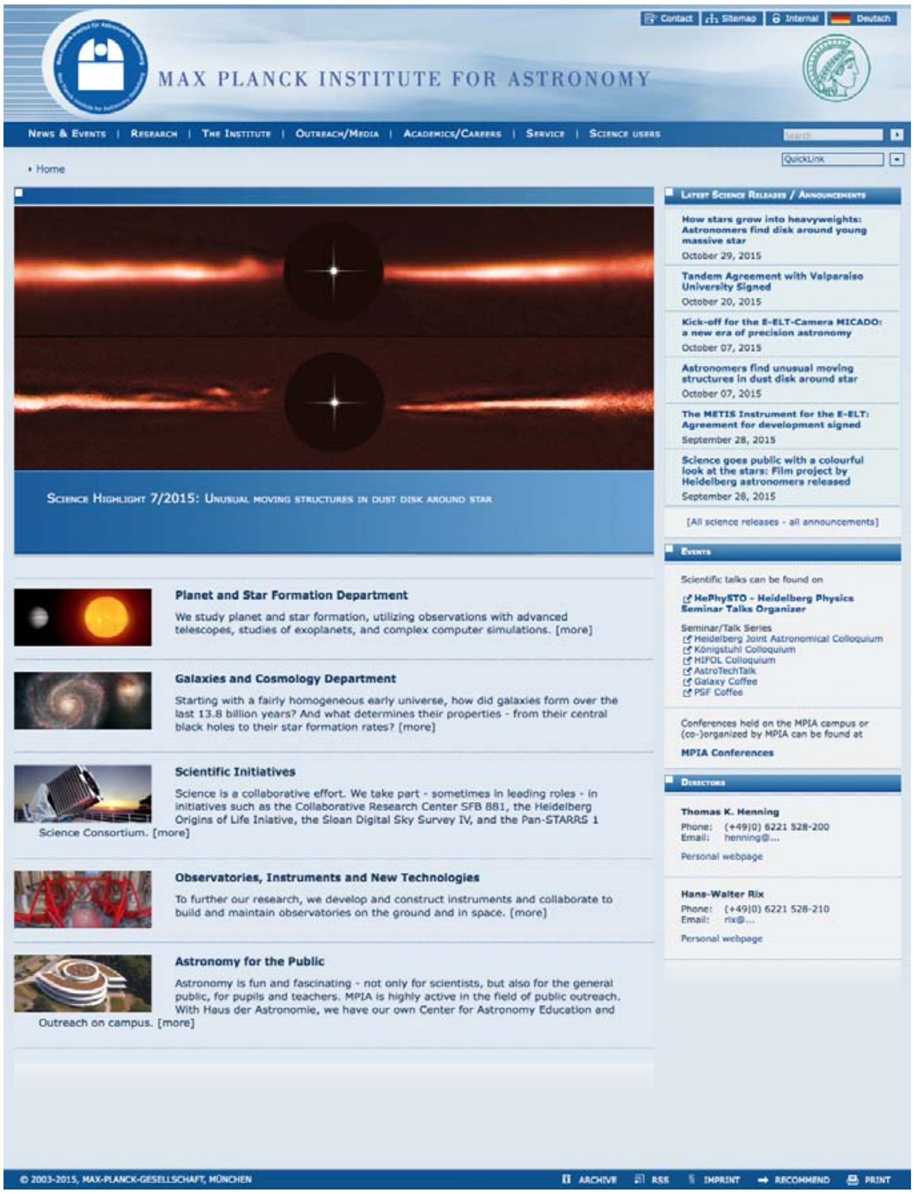
IV.2 Academics, Education and Public Outreach

Outreach

Astronomy is a fascinating subject, and the astronomers at the Max Planck Institute for Astronomy see it as their responsibility to reach out to the general public, to teachers and pupils, and to the media. To that end, our researchers answer media enquiries as well as travelling to locations throughout Germany (and sometimes beyond) to talk to general audiences about their work. In the area of public relations, we communicate our institute's research results both to the media and directly to the general public. For each of the science highlights you can read in chapter II, a press release was created and distributed to selected journalists as well as via the science news service Informationsdienst Wissenschaft (idw).

On suitable occasions, we're also open to the public directly. In collaboration with Haus der Astronomie, there are regular guided tours (organized by A. Quetz) led

Fig. IV.2.1: The new MPIA homepage in June 2015.



Credit: MPIA

Credit: MPIA

Fig. VI.2.2: Girls' Day 2014: Geometric parallax measurements in the Haus der Astronomie.

by the MPIA Outreach Fellows: PhD students who are particularly interested in science outreach, and for whom we provide opportunities for learning and practicing the outreach craft - as an important contribution to their career-building.

This year, we have also been active abroad: With a booth and a planetarium program, we travelled to Jena to the Open Day of the Carl Zeiss Jena GmbH in order to present both our research results and our instrumentation projects.

Internships and Girls' Day

MPIA also has offers aimed directly at high school students. We regularly participate in the nation-wide Girls' Day, with a one-day program aimed at female pupils aged between the ages of 13 and 18 (organization: S. Scheithauer and M. Ebert).

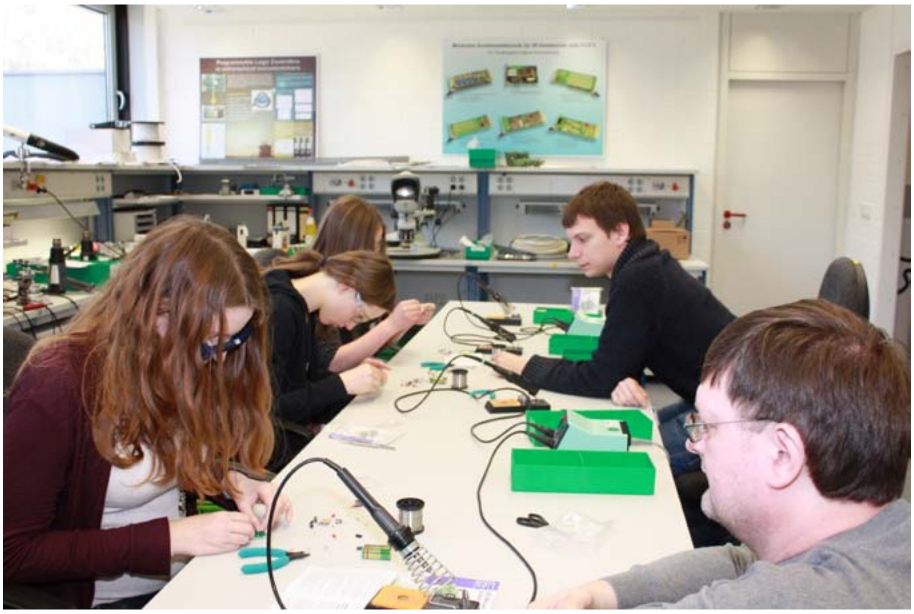
The purpose of Girls' Day is to provide female pupils with the opportunity of experiencing professions in which women are underrepresented. For this year's Girls' Day on March 27, 23 young women experienced different facets of astronomical research and technology development in MPIA and Haus der Astronomie.

On the same date as the Girls' Day, there is a Boys' Day event at Haus der Astronomie. Here, boys are shown how to communicate astronomy to small children (kindergarten or elementary school age).

In addition to MPIA outreach in sensu strictu, MPIA has a close collaboration with Haus der Astronomie (HdA), a center for astronomy education and outreach on our Königstuhl campus, which is operated by the Max Planck Society. The MPG has delegated the responsibility for Haus der Astronomie to MPIA; the managing scientist of HdA is, at the same time, the head of outreach and communications at MPIA.

Another MPIA tradition is the High School Internship program (organization: K. Meisenheimer), aimed at pupils in 10th and 11th grade. In coorperation with the Landessternwarte and Astronomisches Rechen-Institut (both part of Heidelberg University's Center for Astronomy, ZAH), we have been offering an internship program since 2002. This year's internship program, on October 20–24, introduced 14 participants to basic concepts as well as practical methods of astronomy. Topics include black holes and telescopes as well as practical exercises (e.g. on the subject of how a CCD camera works) as well as career information ("How do I get to be an astronomer?").

When it comes to our external image, our major step forward in 2014 was the complete relaunch of our institute website, using the content management system provided by the Max Planck Society for its institutes.



Credit: MPIA

Fig. VI.2.3: Girls' Day 2014: Circuit-making in the MPIA electronics lab.

The relaunch itself was to follow in January 2015. Figure IV.2.1 presents a snapshot of our homepage at the time of this writing in late 2015.

With our relaunch, we reached a number of interrelated goals. On the technical side, the editorial system for the web pages is now as simple as editing Wikipedia, or a blog post, or a word document. As a consequence, a number of MPIA staff members are now involved in keeping the page alive and up to date. We also used the opportunity to re-organize our rich content, introducing new categories like "Science users" to make information accessible as readily as possible. Last but not least, current news now figures much more prominently on our pages, separated into "Science news" presenting our latest research results, and "Institute news" encompassing organizational and personal news items.

Markus Pössel, Klaus Jäger, Axel M.Quetz,
Silvia Scheithauer, Monica Ebert,
and Klaus Meisenheimer

IV.3 Academics, Education and Public Outreach

Haus der Astronomie
Center for Astronomy Education and Outreach

Haus der Astronomie (HdA; literally "House of Astronomy") is the Center for Astronomy Education and Outreach on MPIA Campus. Its mission: to communicate the fascination of astronomy to the general public, to support astronomy education, and to foster the exchange of knowledge between scientists.

Haus der Astronomie is an unusual institution at the interface between science and the public. Its custom-built, galaxy-shaped building hosts an active team of astronomers and astronomy educators, dedicated to developing and producing materials and resources for the public or for use in schools. In 2014, the HdA building received more than 11,000 visitors: members of the general public, here for guided tours or popular talks, student groups from kindergarden to university level, educators and teachers participating in workshops or lectures, and astronomers and engineers attending meetings or conferences.

Fig. IV.3.1: Haus der Astronomie in late summer.

Astronomy for the public

Our outreach activities for the general public combine the tools of classic public relations, online outreach, and the organization of public events. As German node of the ESO Science Outreach Network, we provide support for the German-language outreach activities of ESO, the European Southern Observatory.

On-site events for the public included our monthly series of talks "Fascinating Astronomy" with a total of 18 events and "Sunday a.m. Astronomy" with 4 events. This year, we inaugurated a new category of events called "HdA Highlights." The first highlight talk was given by Michael Kramer from the Max Planck Institute for Radio Astronomy, and it included Kramer handing over a scale model of the Effelsberg radio telescope that has found its permanent place in our exhibition area. The second highlight featured astrophotographer Stefan Seip reporting on his journeys to Namibia. Combined, our public talks, which also included a book presentation by Ernst Peter Fischer,

Credit: HdA / M. Pössel

Abb. IV.3.2: Poster announcing talks in the Haus der Astronomie, created by the MPIA's Graphics Department.


Credit: M. Pössel / HdA

Fig. IV.3.3: Preparing for another year of "Science to School": Discussion session at the meeting of the "Wissenschaft in die Schulen" (WIS) team in June 2014.

drew an audience of almost 3000 visitors. Another special event, our "Space Day" on July 13/14, saw ESA astronaut Reinhold Ewald interacting with a total of 300 visitors, from elementary school classes and high school students to a public audience.

For particularly interested members of the public and in particular for students at the University of Heidelberg, Markus Pössel (with Björn Malte Schäfer) offered a lecture "Cosmology for non-physicists" in the winter term.

As in previous years, the largest external science event we participated in was "Explore Science", July 9-13, the Klaus Tschira Foundation's five-day family science festival, attended by more than 50,000 visitors. HdA staff also gave more than a dozen public talks in various locations throughout Germany.

Scientific Exchange

Haus der Astronomie is regularly used as a venue for scientific conferences, with the central auditorium and the workshop rooms suitable for hosting meetings with up to 80 participants.

The 2014 MPIA Summer Conference "Star Formation: Data, Models and Visualization" in late June was also the first Harvard-Heidelberg Meeting jointly organized by MPIA and the Harvard-Smithsonian Center for Astrophysics. Additional conferences this year included "Intergalactic Matters" in late June, "Exoplanets with JWST-Miri" in late September, the Gaia Challenge meeting in October and the German-Japanese Meeting on Planet Formation in early July.

HdA also served as the venue for the first semester's Heidelberg Joint Astronomical Colloquium as well as for the evaluation of the collaborative research center SFB 881 "The Milky Way System" and for a meeting of Rat Deutscher Sternwarten (RDS), the governing body of Germany's astronomical community.

In the area of astronomy education and outreach, HdA hosted the meeting of the minor planet section of the German amateur astronomy association ("Vereinigung der Sternfreunde"), which was attended by more than 70 participants from Germany, Austria, Switzerland and the Netherlands (organization: C. Liefke with L. Kurtze) and the meeting of the authors of "Wissenschaft in die Schulen" (see below; organized by O. Fischer).

In addition, there were 62 smaller scientific and organizational meetings with a total of 1100 participants.

Astronomy for schools and kindergardens

Our flagship education project remains "Wissenschaft in die Schulen!" (literally "Science into the schools!", abbreviated WIS) in cooperation with the popular astronomy magazine Sterne und Weltraum, which is part of the Spektrum der Wissenschaft family of magazines. WIS astronomy is led by HdA senior staff member Olaf Fischer who, with his team of (mostly external) authors created 15 sets of curricular materials helping teachers bring cutting-edge astronomy into their classrooms, kindly supported by the Reiff Foundation for Amateur and School Astronomy.

Additional educational material for secondary schools was developed by Cecilia Scorza for the Collaborative Research Center "The Milky Way System" (SFB 881) at Heidelberg University, for which HdA is a key outreach partner. Translations into English and Spanish were also distributed to our cooperation partners in the Andean countries (Venezuela, Colombia, Ecuador, Peru, Bolivia and Chile) and in South Africa.

Our most successful product continues to be Universe in a Box, an astronomy kit for use with kindergarden or elementary school children (developed by Cecilia Scorza with contributions from Natalie Fischer). The international office of Universe Awareness successfully launched a kickstarter crowdfunding campaign to share hundreds of these boxes with astronomy educators in underprivileged communities around the world. Interested schools and kindergardens can directly borrow Universe in a Box kits from Haus der Astronomie.

In 2014, a total of 2300 pupils and pre-school children visited HdA for a total of 128 workshops for various age groups. We were particularly happy to welcome a number of schools for special needs and disabled children this year. Such workshops typically involve hands-on activities, make use of our digital planetarium, and are often used to field-test newly developed materials. We developed new workshop concepts in cooperation with Junge Uni Heidelberg and for our colleagues at the Max Planck Institute for Nuclear Physics in Heidelberg.

External events for pupils included astronomy courses for Deutsche Schülerakademie (O. Fischer) and Junior-Akademie Baden-Württemberg in Adelsheim (C. Liefke).

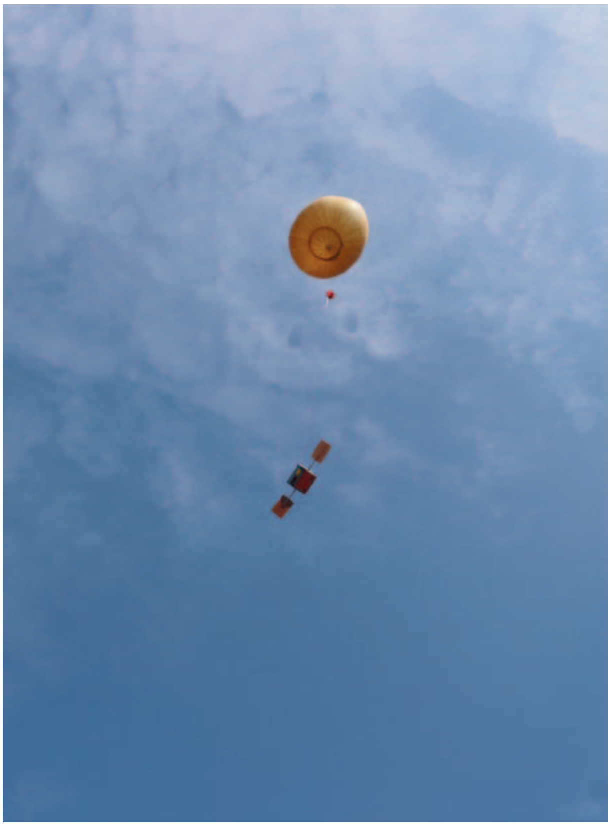
Reaching out to communicators and educators

Teachers and educators play a key role in science outreach – helping them develop a passion for cutting-edge research, and giving them the right tools to pass this passion (and the science itself!) on to their students, is probably the most effective outreach strategy there is.

Pre-service training included two seminars (C. Liefke) as well as the annual block course "Introduction to Astronomy for pre-service teachers" (O. Fischer, C. Liefke, M. Pössel, C. Scorza) at the University of Heidelberg, while Natalie Fischer lectured on "Basic Astronomy in School" at Heidelberg's University of Education (Pädagogische Hochschule).

In-service training included our nationwide three-day training course "Hitchhiker's Guide to the (Milky Way) Galaxy", funded by Wilhelm und Else Heraeus foundation as well as ten training sessions with primary school and kindergarten teachers.

Fig. IV.3.4: As part of the geophysics course at JuniorAkademie Baden-Württemberg in 2014, pupils under the direction of HdA's Carolin Liefke and Dominik Elsässer (Würzburg University) constructed a stratospheric balloon with sensors for temperature, pressure and humidity. The image shows the balloon and the instrument module directly after launch.



Credit: C. Liefke / HdA

Fig. IV.3.5: The on-board digital camera provided impressive images from the stratosphere, at a height of around 20 km. The earth's cloud cover is visible far below the balloon, and the sky is beginning to look dark blue. At the top left, part of the isolation of the instrument module is visible.

Credit: Geophysik-Kurs der JuniorAkademie Baden-Württemberg 2014

External training events included workshops as far apart as Chile, Thuringia and Baden-Wurttemberg, while this year's mobile teacher training, supported by the Reiff Foundation, took place in Schleswig-Holstein (Flensburg, Marne, Heide, Ahrensburg, Bad Segeberg; O. Fischer/Sascha Soh). The "Telescope Driver's Licence" workshop in Adelsheim qualifying teachers for the use of small telescopes in school went into another round in November (O. Fischer/C. Liefke). The course also qualifies teachers for HdA's telescope lending program. Our bi-national German-Italian Summer School, also funded by the Wilhelm and Else Heraeus foundation, continued in Padua on the topic of Active Galactic Nuclei in September. Members of the UNAWE Network coordinated by Natalie Fischer reached more than a hundred new elementary school teachers in various training sessions.

Research with high-school students

HdA provides first-hand research experience for high-school students in several different programs. In the framework of the IASC-Pan-STARRS asteroid search campaigns, high-school students search for asteroids in Pan-STARRS image data, with a realistic chance of discovering previously unknown main belt asteroids. Within this framework, we supported a total of 26 German high-school groups participating in three search campaigns (Liefke).

In the field of remote observing (telescopes that can be controlled via the Internet; Liefke), we faced considerable challenges in 2014: While our collaboration with the Faulkes Telescope Project has now been formalized with a memorandum of understanding, a re-design of the telescope's operating interface by the operators, Las Cumbres Observatory Global Telescope Network (LCOGT), led to the loss of the real-time observing experience and necessitated the development of completely new documentation for the participating teachers. Using these telescopes, we organized two concerted themed observing days on exoplanet transit lightcurves with German and Austrian schools and, in May, a teacher training dedicated to image processing tools.

We also signed a memorandum of understanding with the Foundation Interactive Astronomy and Astrophysics, Tübingen, regarding HdA use of, and support for the 60 cm ROTAT remote telescope at Observatoire de Haute Provence, France

Our internship program in 2014 once more consisted of career orientation (BOGY internships) and of programs for the benefit of particularly talented/interested students, notably in collaboration with the Hector Seminar or the Heidelberger Life Science Lab (C. Liefke). The highlight was our three-week International Summer Internship (M. Pössel), which regularly includes participants from the International Summer Science School Heidelberg. This year, seven pupils, from Australia, France, Germany, Israel and Italy took part in the program.

Keeping connected: networking

Internationally, our main collaborations are in the framework of the EU-UNAWE network (that is, with our counterparts in Italy, the Netherlands, the United King-

Fig. IV.3.6: At the 2014 edition of Space Day at HdA on July 13, ESA astronaut Dr. Reinhold Ewald talked to school children and to a general audience about his experiences aboard the MIR space station and about the International Space Station ISS. Ewald is also a member of MPIA's Board of Trustees.

Credit: HdA / M. Pössel

Credit: HdA / M. Pössel

Fig. IV.3.7: Exoplanets for kids: Guido Thimm (ZAH) explains our solar system and its distant siblings in a special family edition of our lecture series "Astronomie am Sonntagvormittag" in October 2014.

dom, South Africa and Spain) as well as cooperating institutions in Chile (in cooperation with the Heidelberg University's Center for Astronomy and its Centre of Excellence in Chile). Cecilia Scorza has also been active in Colombia, Venezuela, Ecuador, Peru and Bolivia, helping to set up the Andean node for the IAU's Office of Astronomy for Development, which was approved in November 2014.

A new and very promising collaboration is that with the "ESO Supernova" (ES), a younger (and larger) sibling for HdA to be built in Garching. ES is a joint project of the European Southern Observatory ESO with the Heidelberg Institute for Theoretical Studies (HITS), funded by the Klaus Tschira Foundation. HdA, in particular through the work of Cecilia Scorza, is deeply involved in creating educational content for ES, which is used to develop planetarium shows, exhibition content for K-13 an educational guided tour, and school workshops. Contributions include teacher training development, a strategy for building a teacher network at the ES, and the collaborative project "50 Concepts" together with partners at Leiden Observatory, to increase astronomy literacy in European schools.

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

Haus der Astronomie is the result of a partnership between the Klaus Tschira Foundation, which has financed and built the spectacular HdA building, the Max Planck Society operating the HdA (via MPIA), and the City of Heidelberg and the University of Heidelberg supporting our operations with staff positions.

V. People and Events

V.1 People and events

Honours, Grants and Awards

As in the preceding years, our staff members received several important awards for their achievements both in science and beyond.

Christian Doppler Prize for Lisa Kaltenegger

On June 13, 2014, Lisa Kaltenegger received the Christian Doppler Prize of the Land Salzburg, the highest regional award for young scientists. The prize – which includes a purse of 12,000 Euros – honours Kaltenegger's work in the field of exoplanet research.

The prize was instituted in 1972, and is awarded by the Provincial Government of Salzburg for outstanding scientific and technical achievements and inventions in the natural sciences. In 2014, awards were handed out in four categories. Kaltenegger received the award in the category of outstanding applications of the Doppler principle, for technical sciences, mathematics and physics.

Christian Doppler (1803–1853) was an Austrian mathematician and physicist born in Salzburg. He is best known for the effect that bears his name: Due to the Doppler effect, an observer will measure a frequency shift for radiation whose source is in motion relative to him or her. An everyday example for sound is the contrast between the higher pitch of an approaching car as compared to the slightly deeper pitch when the same care is moving away from the listener.

The Doppler effect also changes the frequencies of light emitted by a moving source – and is particularly noticeable for celestial bodies moving at high speeds. In that case, the change in frequency causes a shift of spectral lines towards the red or the blue end of the spectrum, depending on whether the object moves away from us or towards us. An important application is the detection of planets around stars other than the sun from an analysis of the spectra of their host stars – which is possible even when you cannot see the planets directly. The light of a star undergoes a periodic Doppler shift when its movement is affected by the gravity of an orbiting planet.

The research of Lisa Kaltenegger focuses on a fairly new field of research: exoplanets that might be similar to earth. Kaltenegger is currently developing models which will teach as about the observable properties by which such "habitable worlds" might be eventually be identified. Typical spectral features, caused by the composition of the planet's atmosphere, should play an important role in this analysis.

Credit: LMZ / Otto Wieser

Fig. V.1.1: Doppler-Award presented to Lisa Kaltenegger by Mag. Martina Berthold, member of the regional government of Salzburg.

The prize was awarded by an independent jury, with input from international experts. The award was presented by Martina Berthold, a member of Salzburg's regional government.

Fizeau Investigator Prize for Christoph Leinert

The Fizeau Prize for "outstanding achievement in fundamentals and implementation of optical interferometry" has been awarded by Commission 54 (Optical and Infrared Interferometry) of the International Astronomical Union (IAU), the Observatoire de la Côte d'Azur (OCA), and the Mt. Wilson Institute (MWI) since 2010. The 2014 prize was awarded to Christoph Leinert from MPIA "for his considerable scientific achievements throughout his career, and specifically for his role as

Credit: MPIA / K. Jäger

Fig. V.1.2: Christoph Leinert giving a talk at MPIA.

Principal Investigator for the MIDI instrument on the Very Large Telescope Interferometer (VLTI)."

In its citation, the prize committee writes: "His noteworthy career connects to a recurring theme of high angular resolution astronomy, which ultimately led him to long-baseline interferometry at the VLTI. The remarkable success of MIDI can be directly connected to the scientific and technical leadership of Professor Leinert, resulting in breakthroughs in our understanding of active galactic nuclei, protoplanetary disks, and circumstellar envelopes of asymptotic giant branch stars; this leadership has also been instrumental in significantly expanding the interferometry user community. Professor Leinert's success with the VLTI is inspiring the next generation of researchers and instrumentation to build on these successes."

MIDI works at mid-infrared wavelengths and was built by seven institutes under the direction of MPIA, with Christoph Leinert (Project Scientist) and Uwe Graser (Project Manager) as the Principal Investigators (PIs). The high resolution is achieved by combining the light beams of two telescopes on Paranal (either from the 8.2m Unit Telescopes or from the 1.8m Auxiliary Telescopes). MIDI was the first interferometric instrument offered to the community at Paranal, and an important step towards the upcoming generation of instrumentation at the VLTI, such as the MATISSE instrument (in which MPIA is also involved).

Fig. V.1.3: The complex MIDI instrument in the interferometric laboratory of the ESO Very Large Telescope (VLT) at Paranal Mountain in Chile.

Credit: MPIA / ESO

Fig. V.1.4: Benjamin Hendricks

Fig. V.1.5: Miguel Querejeta

Patzer Prize 2014

The annual Ernst Patzer Prize honours the best publications by young scientists (namely graduate students or postdocs less than three years after completion of their PhD). The publications must have been published in a refereed journal.

The Prize was donated by the art-lover and philosopher Ernst Patzer and established by his widow. The Foundation awards its prizes to young researchers at MPIA and other institutes in Heidelberg and wishes to support research particularly in the field of astronomy. The selection committee consists of two scientists from MPIA and one additional external scientist from Heidelberg.

This year's Patzer prize winners are:

- **Benjamin Hendricks** (ZAH/LSW) for his publication "The metal-poor knee in the Fornax dwarf Spheroidal galaxy". ApJ, 785, 102 (2014)
- **Miguel Querejeta** (MPIA) for his publication "The Spitzer Survey of Stellar Structure in Galaxies (S4G): Precise Stellar Mass Distributions from Automated Dust Correction at 3.6 microns. ApJ Suppl., 219,5Q (2015)
- **Nikolay Kacharov** (ZAH/LSW) and **Paolo Bianchini** (MPIA) for their publication "A study of rotating globular clusters: The case of the old, metal poor globular cluster NGC 4372". A&A, 567, A69 (2014)

The award ceremony was held on November 28 in the auditorium of the Max Planck Institute for Astronomy.

Precision Engineering Workshop and Personnel Department Awarded by MPG for Innovative Vocational Training

Each year, the Max Planck Society presents their "Ausbildungspreis" awards to highlight innovative schemes for vocational training. This year's winners include both the precision mechanical workshop at MPIA and our administration, specifically the personnel department.

The prize committee includes educators as well as members of the Max Planck Society general works council (GBR), representatives of the trainees (GJAV) and the society's general administration (GV).

The prize is meant to express appreciation for all those involved in MPG vocational training. Prize-worthy features include the development of innovative training concepts, a high level of support for trainees, special offers for cooperating with external partners, or providing additional qualifications. The award includes prize-money amounting to 7500 Euro, which is to be used to further vocational training.

The precision mechanical workshop received the award for introducing both a new format of challenging technical discussions as well as for their "Projektwoche" phases, in which regular teaching is replaced by work on

Credit: MPIA / D. Anders

Fig. V.1.6: Nikolay Kacharov

Credit: MPIA / D. Anders

Fig. V.1.7: Paolo Bianchini

a common project.

MPIA's human resources department was recognized for its interdisciplinary training project for apprentices, "Work and Family: My Life", and the development, evaluation and presentation of a poll among MPIA employees.

Fig. V.1.8: The MPIA Precision Mechanics Workshop.

Credit: MPIA / Doris Anders

Trainee Award 2014 of the Max Planck Society for Anica Till

The Max Planck Society Trainee Prize for outstanding achievements in vocational training is now in its eighth year. One of the winners for the year 2014 is Anica Till from MPIA's administration department.

The prize recognizes not only outstanding professional performance throughout the training phase, but also the trainees' personal development and social commitment.

Anica Till has shown excellent performance since the beginning of her training as office clerk in MPIA's administration department. The MPG prize is not her first: in 2013, she received the "Förderpreis des Unternehmenskreises Mosbach", the "Preis des Fördervereins für Bürokaufleute der Ludwig-Erhard-Schule", and the "Mosbach-Urkunde der Ludwig-Erhard-Schule" for outstanding achievements in her school training (see MPIA Annual Report 2013, page 86).

Quelle: MPIA / D. Anders

Fig. V.1.9: Anica Till.

Additional awards in 2014

- The first discovery of a filament of the cosmic network was recognized by the editors of Physics World as one of their top ten breakthroughs in physics 2014. The discovery was made by Fabrizio Arrigoni Battaia and Joseph Hennawi from MPIA, as well as Sebastiano Cantalupo, Piero Madau and Xavier Prochaska from University of California at Santa Cruz, USA.
- Thomas Henning, director of MPIA's Planet and Star Formation department, was invited by Penn State University to hold the prestigious Russell Marker Lectures in Astronomy and Astrophysics 2014. The lectures were introduced in 1984 and are sponsored by Penn State's Eberly College of Science.
- Stefan Hippler was appointed "Chinese Academy of Sciences Visiting Professor for Senior International Scientists".
- Anna Ho received a National Science Foundation Graduate Research Fellowship, a Fulbright Scholarship and an Ida M. Green Fellowship from the Massachusetts Institute of Technology (MIT). She won the Karl Taylor Compton Prize, also from MIT. In addition, she was awarded a Ford Foundation Fellowship and received an honorable mention in the Chambliss Astronomy Achievement Student Awards.
- Melissa Ness received the JG Crawford Prize of the Australian National University.
- Dmitry Semenov won an individual research budget (SE 1962 / 1–3, 2014–2016) by the German Research Foundation (DFG) for his project "The first 10 million years of the solar nebula" in the framework of the priority program SPP 1385.
- Svitlana Zhukovska received research funding from the German Research Foundation (DFG) within the priority program 1573 "Physics of the Interstellar Medium".
- Kathryn Kreckel was awarded the prize for the best poster presentation at the conference "Multi Wavelength Surveys: Galaxy formation and evolution from the early universe to Today" in Croatia in May 2014.

V.2 People and Events

Special Events and Conferences

As in many years before, MPIA scientists organized local and external conferences or participated significantly in the organization and management of other meetings.

This year's **MPIA Summer Conference** (from June 23.–26.) at the Haus der Astronomie (HdA) on MPIA campus was the first joint science conference between Heidelberg and Harvard. Entitled **"Star Formation: Data, Models and Visualization"**, the workshop was focused on studies of the star formation within our Galaxy, as well as on current and future visualization tools and techniques that can support studies of this kind. One particular aspect was the discussion about the special requirements arising from the huge amount of data for modeling and related aspects for visualization.

Just before, between June 16 and June 20, we had a weeklong workshop entitled **"Intergalactic Matters"** also at the HdA. Its aim was to bring together experts working in the field of the intergalactic medium (IGM) which plays an important role regarding the evolution and history of cosmic structure formation.

But there were further larger meetings and conferences at the MPIA campus in 2014 and the following list shows a selection:

- Quenching and Quiescence – "What slows down and stops star formation in Massive galaxies?" (MPIA, July 14–18)
- Chemical Diagnostics in the ALMA/NOEMA Era (HdA, July 21–23)
- Gaia Challenge Workshop 2014 (HdA, October 27–31)
- German-Japanese Meeting on Planet Formation, Detection and Characterization (HdA, November 4–7)

Fig. V.2.1: The participants of the MPIA Summer Conference 2014, the first joint science conference between Heidelberg and Harvard, in front of the Haus der Astronomie on the MPIA-Campus.

Credit: HdA / M. Pössel

The yearly visit of MPIA by the **Board of Trustees** took place at December 1. The Board provides important support to the Institute in questions of academic policy, public perception and contacts in society. The Institute management provided detailed information on special developments in the Institute with a particular emphasis on instrumentation projects and science.

Another part of the academic life at MPIA was an internal symposium called **MPIA Science Day** on December 9. 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 various research projects at the Institute.

Furthermore, the Joint Astronomical Colloquium of all astronomical institutes in Heidelberg was held at HdA/MPIA between April and July (13 sessions) and we had another welcome event for new students and postdocs at the Institute on November 25.

Between September 22 and 26, the 9th Heidelberg **IMPRS Summer School** took place at the Max Planck House in downtown Heidelberg. This year the topic was **"Frontiers of Stellar Structure and Evolution"** and the workshop was again a combination of scientific presentations, lectures, and hands-on exercises.

Additionally, we had a significant number of conferences organized or co-organized by MPIA staff members taking place at Ringberg Castle near Tegernsee, which is a special meeting venue of the Max-Planck-Society. These conferences were:

- "The Early Phase of Star Formation (EPOS) 2014", June 1–6.
- "Astrophysical calibration of Gaia and other surveys", July 7–11.
- "The Grenoble-Heidelberg Meeting on Star Formation", October 12–15.
- "Getting ready for Planetology beyond the Solar System", November 17–21.
- "The quest for Dark Energy II", December 14–19.

MPIA and HdA were also involved in the Fall Meeting of the German Astronomical Society (AG) through organizational support but also through scientific presentations, teacher training, and a special meeting for Public Outreach in Astronomy. The conference entitled "The Variable Sky: from Tiny Variations to Big Explosions", was held in Bamberg (September 22–26)"

MPIA and HdA also organized again a local program during the Girls' Day (May 27) and provided (together with the ZAH institutes) a one-week internship for pupils from high school (October 20 – 24). The MPIA and HdA also took part in supervising schoolchildren during a practical training module of the International Science School Heidelberg (ISH) in July and August. The ISH is a student exchange project of the city of Heidelberg in collaboration with its partner cities. In addition to participating in educational activities, the MPIA is a member of the ISH scientific council.

More details on a number of other activities mainly related to public outreach can be found in Chapter IV.

V.3 People and Events

Work and Family: Dual Careers and Work Life Balance

Science offers the opportunity for careers that are demanding and rewarding – but which also come with their own challenges. At a certain time of their lives, young scientists will face the problem of balancing their work and a fulfilled family life. Creating a family-friendly environment is also seen as a key element for creating equal opportunities in science for men and women alike.

A career in research demands both flexibility and mobility. In particular in its early stages, during the PhD and postdoc phases, scientists regularly change their places of work (and, not infrequently, their country or even continent of residence). For dual career couples, in which both partners pursue a scientific career, this creates significant challenges. That is why an institute's family-friendly strategy must necessarily include a concept for how to handle the challenges of dual careers, creating adequate career opportunities also for the spouse or partner of scientists newly joining the institute.

A more general perspective is that of work-life balance – of a well-rounded life in which both work and career on the one hand, and play and family life on the other have their proper place.

The Max Planck Institute for Astronomy has long striven to create family-friendly conditions both for its scientific and its non-scientific staff – with success, as is shown, among other things, by several awards the program has received. In 2014, the qualification project for apprentices, "Career and Family – My Life" was awarded the Max Planck Society's Vocational Training Price (Ausbildungspreis).

Family-friendly MPIA

- Flexible work times and work locations in special situations (e.g. when child care is needed, time for caring for elderly relatives, or in dual career situations)
- Reserved places in child care facilites for children between the ages of 8 weeks and 6 years; a total of 23 places for the MPIs in Heidelberg
- Child care room and baby-friendly office in the institute
- Child care during conferences
- Holiday child care offers via Bündnis für Familie Heidelberg
- Dual career programs
- "Keep in touch" program for employees that need temporary leave from their job due in special situations

Fig. V.3.1: Quantenzwerge building on the grounds of the Max Planck Institute for Nuclear Physics.

Credit: Max Planck Institute for Nuclear Physics

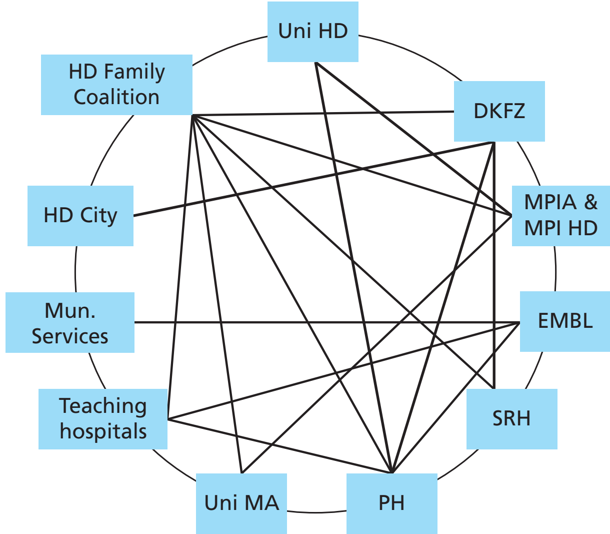
- Support for fathers' parental leave
- Support program for finding accomodation, suitable schools and child care as new employees move to Heidelberg, by the institute's International Office
- "Besser betreut" service clearing house for child care, senior care, house-cleaning and similar services

Creche and Kindergarden "Quantenzwerge" ("Quantum Dwarfs") opens its doors

Availability of child care services is a key element in family-friendly career management. In October 2014, the combined creche and kindergarden (Kindertagesstätte) "Quantenzwerge" opened on the grounds of the Max Planck Institute for Nuclear Physics. It is operated by "Kinderzentren Kunterbunt" and is open for employees of all Max Planck Institutes in Heidelberg. With a total of 50 places for children, "Quantenzwerge" can accomodate children between six months of age and their first day of school. There are three creche groups with 10 places each, and a kindergarden group with 20 places. For the

Fig. V.3.2: Logo of the "Quantenzwerge" crèche and kindergarden.

Credit: Max Planck Institute for Nuclear Physics



Credit: MPIA

Fig. V.3.3: Institutional members of the Dual Career Network in and around Heidelberg.

Max Planck Institute for Astronomy, this is an important additional step towards providing family-friendly conditions for all of its employees.

Stepping up the Dual Career services

Dual Career services have proved time and again their importance for creating a family-friendly MPIA. Polls among scientists negotiating for tenured positions in the Max Planck Society show that a spouse's or partner's career chances play an important role in more than half of the negotiations. At MPIA, Dual Career services are offered whenever there is recruitement for permanent scientific staff positions, postdoc positions, or technical and scientific support staff.

In 2014, the Dual Career network extended its cooperation with comparable networks in Karlsruhe, Frankfurt and Stuttgart in order to enlarge the pool of positions available to dual careers partners.

As a next step, the Dual Career Network will revamp its web-based job portal, which has been online since 2009. In its new incarnation, the portal strives for increased usability, and a more modern design. Ingrid Apfel (MPIA) and Senni Hundt (Heidelberg University) presented the concept of the job portal at the regional strategy conference "Familienbewusst Fachkräfte Sichern" (Safeguarding Qualified Employees via Family-Awareness) for the Rhein-Neckar Region in March 2014 at the University of Heidelberg.

Ingrid Apfel

VI. Appendix


Astronomy & Astrophysics
Astronomy & Astrophysics
THE ASTRONOMY AND ASTROPHYSICS REVIEW
Elektronik messen+testen
CERNCOURIER
elektro AUTOMATION
c't magazin für computer technik
So läuft Ihr Handy länger
LibreOffice-Tipps
150 %
Elektronik
Journal of Astronomical Instrumentation
Journal of the Optical Society of America A
OPTICS, IMAGE SCIENCE, AND VISION
Journal of the Optical Society of America B
OPTICAL PHYSICS
MONTHLY NOTICES of the Royal Astronomical Society
OXFORD
nature
Weed out Bad
Optics Letters
CERNCOURIER
CMS and the LHC Run 1 legacy
SCIENTIFIC AMERICAN
SPECIAL REPORT
LEARNING IN THE DIGITAL AGE
PHYSICAL REVIEW LETTERS
physics today
revista mexicana de astronomía y astrofísica
Science
SKY & TELESCOPE
Making Massive Stars
Spektrum DER WISSENSCHAFT
100 Jahre Einsteins Raumzeit
Spektrum neo
Die Welt im Jahr 2050

VI. Appendix

VI.1 Staff

Department: Planet and Star Formation

Director: Thomas Henning

Infrared Space Astronomy: Oliver Krause, Zoltan Balog, Jeroen Bouwman, Örs Hunor Detre, Ulrich Grözinger, Ulrich Klaas, Hendrik Linz, Friedrich Müller, Markus Nielbock, Silvia Scheithauer, Jürgen Schreiber

Star Formation: Henrik Beuther, Angela Adamo, Tobias Albertson, Amelia Bayo, Simon Bihr, Arjan Bik, Paul Boley, Markus Feldt, Siyi Feng, Thomas Gerner, Katharine Johnston, Jouni Kainulainen, Ralf Launhardt, Nils Lippok, Johan Olofsson, Sarah Ragan, Dimitry Semenov, Amy Stutz, Roy van Boekel, Shiwei Wu, Svitlana Zhukovska

Brown Dwarfs/Exoplanets: Reinhard Mundt, Roy van Boekel, Wolfgang Brandner, Simona Ciceri, Ian Crossfield, Esther Buenzli, Niall Deacon, Bertrand Goldman, Viki Joergens, Luigi Mancini, Elena Manjavacas, Christian Obermeier, Taisiya Kopytova, Florian Rodler

Theory (PSF): Hubertus Klahr, Kai-Martin Dittkrist, Karsten Dittrich, Alexander Horn, Aiara Lobo Gomes, Natascha Manger, Mykola Malygin, Christoph Mordasini, Gabriel-Dominique Marleau, Paul Mollière, Andreas Schreiber, Matthäus Schulik

Laboratory Astrophysics: Cornelia Jäger, Abel Brieva, Daniele Fulvio, Serge Krasnokutsky, Karsten Potrick, Gael Rouillé, Toulou Sabri

Frontiers of Interferometry in Germany FRINGE: Thomas Henning, Uwe Graser, Ralf Launhardt, Jörg-Uwe Pott, Roy van Boekel, Johan Olofsson, Adriana Pohl

Adaptive Optics: Wolfgang Brandner, Casey Deen, Markus Feldt, Stefan Hippler, Sarah Kendrew, Maria Wöllert, Pengqian Yang

MPG Research Group: Sternentstehung in der Milchstraße: Thomas Robitaille, Amanda Heidermann, Christine Koepferl, Esteban Morales

Emmy-Noether-Group: Charakterisierung extrasolarer Planeten: Lisa Kaltenegger, Siddharth Hegde, Yamila Miguel, Yan Betremieux

Department: Galaxies and Cosmology

Director: Hans-Walter Rix

Galaxy Evolution and Milky Way: Hans-Walter Rix, Yu-Yen Chang, Nina Hernitschek, Jakob Herpich, Marie Martig, Michael Maseda, Melissa Ness, Edward Schlafly, Branimir Sesar, Wilma Trick, Arjen van der Wel, Xiangxiang Xue, Zhitai Zang, Greg Stinson

Gaia Galactic Survey Mission: Coryn Bailer-Jones, René Andrae, Tri Astraatmadja, Fabo Feng, Richard Hanson, Dae-Won Kim, Kester Smith, Sara Rezaeikhoshbakht, Morgan Fouesneau

Interstellar Matter and Quasars with high Redshift: Fabian Walter, Elisabete Da Cunha, Anahi Caldu Primo, Roberto Decarli, Emanuele Farina, Jorge González, Jacqueline Hodge, Maria Kapala, Nico Krieger, Eduarodo Banados Torres, Bram Venemans, Laura Zschaechner, Carl Ferkinhoff

High Definition Astronomy: Thomas Herbst, Derek Kopon, Kalyan K. Radhakrishnan, Joshua Schlieder, Zhaojun Yan, Xianyu Zhang

Jet Physics of Active Galactic Nucle: Christian Fendt, Somayyeh Sheikhnezami, Deniss Stepanovs, Qian Qian

Active Galactic Nuclei: Klaus Meisenheimer, Christian Leipski, Bernhard Dorner, Patrick Fopp

Extragalactic Star Formation: Eva Schinnerer, Paolo Bianchini, Emer Brady, Annie Hughes, Sharon Meidt, Mark Norris, Miguel Querejeta, Fatemeh Tabatabaei

Coevolution of Galaxies and Black Holes (Emmy Noether Group) and EUCLID Mission Group: Knud Jahnke, Stefanie Wachter, Liyualem Ambachew, Felix Hormuth, Katherine Inskip, Matt Mechtley, Gregor Seidel, Robert Singh

Inter- and Circumgalactic Medium: Joe Hennawi, Fabrizio Arrigoni Battaia, Anna Christina Eilers, Cristina Javiera Garcia, Ilya Khrykin, Girish Kulkarni, Khee-Gan Lee, Elisabeta Lusso, Gabriele Maier, Jose Onorbe, Alberto Rorai, Tobias Schmidt, Jonathan Stern, Michael Walther, Gabor Worseck

Structure and Dynamics of Galaxies: Glenn van de Ven, Remco van den Bosch, Alex Büdenbender, Vesselina Kalinova, Chen Fanyao, Sladjana Nikolic, Athanasia Tstasi, Akin Yildirim, Ling Zhu

Galaxy Formation in a Dark Universe: Andrea Macciò (Max-Planck-Forschungsgruppe), Salvatore Cielo, Aaron Dutton, Nikolaos Fanidakis, Thales Gutcke, Rahul Kannan, Camilla Penzo, Liang Wang, Rainer Weinberger, Edouard Tollet

Instrumentation: Thomas Herbst, Zhaojun Yan, Xianyu Zhang

Instrumentation, Black Holes and Accretion: Jörg-Uwe Pott, Santiago J. Barboza, Michael Boehm, Iva Karovicova, Alexander Keck, Rainer Köhler, Kirsten Schnuelle

Galactic Nuclei: Nadine Neumayer (Max Planck Research Group), Iskren Yordanov Georgiev

Other staff

Scientific coordinator: Klaus Jäger

MPIA Observatories: Roland Gredel

Public Relations: Markus Pössel (Head), Klaus Jäger und Axel M. Quetz

Haus der Astronomie: Pössel (Managing Scientist) Sigrid Brümmer-Wissler, Natalie Fischer, Olaf Fischer, Carolin Liefke, Alexander Ludwig, Matthias Penselin, Tobias Schultz, Cecilia Scorza, Elena Sellentin; *Interns, Student assistents:* Sophia Haude, Elena Kozlikin, Sebastian Neu, Valentina Rohnacher (until Nov. 30), Sascha Soh (Nov. 1–30)

Technical Departments: Martin Kürster (Head)

– **Engineering Design:** Ralf-Rainer Rohloff (Head), Harald Baumeister (Deputy), Monica Ebert, Armin Huber, Norbert Münch

– **Precision Mechanics Workshop:** Armin Böhm (Head), Stefan Meister (Deputy), Julian Baldauf (Feb. 20 until Sep. 30), Mario Heitz, Jan-Philipp Kugler (Feb. 20 until Aug. 31), Tobias Maurer, Klaus Meixner, Stadler; *Trainees, Interns, Student assistents:* Julian Baldauf (until Feb. 19), Jan-Philipp Kugler (until Feb. 19), Nico Mayer, Francisco Ortiz (since Sep. 1), Lukas Reichert, Matthias Christoph Schend, Christoph Schwind, Felix Sennhenn, Alexander Specht

– **Electronics:** Lars Mohr (Head), Jose R. Ramos (Deputy), Tobias Adler, Matthias Alter, Heiko Ehret, Ralf Klein, Michael Lehmitz, Ulrich Mall, Achim Ridinger, Frank Wrhel; *Trainees, Interns, Student assistents:* Verena Grimm (1.3. until 31.8.), Peter Pflanzl (ab 1.9.), Linda Ramisch (until 31.5.), Roland Wydra (until 31.8.)

– **Software:** Florian Briegel (Head), Udo Neumann (kommissarischer Deputy), Clemens Storz (Deputy), Jürgen Berwein, José Borelli, Frank Kittmann, Martin Kulas, Richard Mathar, Aleksei Pavlov

– **Instrumentation:** Peter Bizenberger (Head), Thomas Bertram (Deputy), Albert Conrad (until July 31), Fulvio De Bonis (until Feb. 28), Wolfgang Gässler, Uwe Graser, Dieter Hermann, Ralph Hofferbert, Werner Laun, Marcus Mellein, Javier Moreno-Ventas, Eric Müller (since Aug. 1), Vianak Naranjo (parental leave until May 25), Johana Panduro, Diethard Peter; *Trainees, Interns, Student assistents:* Timothy Herbst (Aug. 1 until Sep. 30), Hagen Schray (until Jan. 31), Jonathan Slawitzky (since Nov. 1)

Administrative and Technical Service Departments:

– **Library:** Monika Dueck

– **IT Department:** Donald Hoard (Head, since Sep. 1), Marco Piroth (Head until Aug. 31), Frank Richter (Deputy until Aug. 31), Björn Binroth (Deputy since Sep. 1), Ulrich Hiller, Andreas Hummelbrunner

– **Photographic Lab:** Doris Anders

– **Graphics Department:** Axel M. Quetz (Head), Karin Meißner, Carmen Müllerthann (parental leave since Mar. 1), Judith Neidel (since Feb. 1)

– **Secretariats:** Nina Bader (July 1 until Sep. 30), Sandra Berner, Carmen Cuevas-Alonso (until June 30), Carola Jordan (since Nov. 1), Susanne Koltes-Al-Zoubi (parental leave until Oct. 31), Sabine Otto, Daniela Scheerer, Heide Seifert, Thu Huong Witte-Nguy (parental leave)

– **Technical Services and Cafeteria:** Frank Witzel (Head), Markus Nauß (Deputy), Hartmut Behnke, Sascha Douffet, Gabriele Drescher, Marion Jung, Pascal Krämer, Frank Lang, Britta Witzel, Elke Zimmermann

– **Administration:** Mathias Voss (Head), Ingrid Apfel (Deputy), Danuta Hoffmann (Deputy), Arnim Wolf (Deputy); *Purchasing Dept.:* Arnim Wolf, Doris Anders; *Finances Dept.:* Danuta Hoffmann, Doris Anders, Gerda Braun (until Mar. 31), Heidi Enkler-Scharpegge, Marc O. Lechner, Manuela Reifke, Christine Zähringer; *HR Dept.:* Ingrid Apfel, Jana

Baier (parental leave), Carmen Braun (Feb. 1 until May 31), Christiane Hölscher, Lilo Schleich, Silke Hoffmann (since June 1), Tina Wagner; *Information:* Ina Beckmann, Mary M. Dehen (since Sep. 1); *Trainees, Students:* Henock Lebasse (since Sep. 1), Anica Till, Aaron Sievers (Apr. 1 until May 31)

Former Staff Members Acting for the Institute: Josef Fried, Christoph Leinert, Dietrich Lemke, Rainer Lenzen, Jakob Staude

VI.2 Visitors List

Scientific visitors: László Szücs, ITA HD, Jan. 7–24; Chiara Mazzucchelli, Univ. of Central Florida, Jan. 9–Feb. 15; Carmen Montuori, Univ. dell'Insubria, Jan. 12–26; Massimo Dotti, Univ. Milano, Jan. 12–26; Guillermo Blanc, Carnegie Inst., Jan. 14–Feb. 1; Vitaly Akimkin, Russ. Acad. Sci., Jan. 27–Feb. 14; Andreu Arinyo Prats, IEEC, Jan. 27–Apr. 30; Antonella Iannella, Univ. Salerno, Feb. 1–May 31; Sandor Kiraly, Konkoly Obs, Feb. 3–May 31; Sarah Rugheimer, Harvard, Feb. 17–Mar. 11; André Germeroth, ZAH/LSW HD, Mar. 1–31; Yaroslav Pavlyuchenkov, Russ. Acad. Sci., Mar. 29–Apr. 14; Aura Obreja, Madrid, Apr. 1–June 30; Aaron Sievers, Kirchhoff-Institut für Physik, Univ. Heidelberg, Apr. 1–May 31; Chiara Mazzuchelli, UCF: CAH, Apr. 1–Aug. 31; Lorenzo Posti, Univ. Bologna, Apr. 28–May 29; Edouard Tollet, Univ. Heidelberg, Apr. 28–July 30; Jan Philip Sindel, Univ. Heidelberg, May 1–Aug. 1; Gesa Grüning, Univ. Heidelberg, May 1–Aug. 1; Marcel Lotz, Univ. Heidelberg, May 1–July 31; Carsten Steckbauer, Univ. Heidelberg, May 5–Aug. 5; Trey Jensen, University of Utah, May 12–Aug. 1; Greg Rudnick, Univ. Kansas, May 19–June 5; Arnold Guscik, Konkoly Obs., June 1–July 31; David Neb, Univ. Heidelberg, June 1–July 31; Justine Devin, Univ. Strasbourg, June 2–Aug. 31; Eve Mattaey, Princeton University, June 3–Aug. 15; Ryan Leaman, IAC, June 7–28; Serena Kim, Steward Obs., June 10–24; Xiahui Fan, Steward Obs., June 10–24; Gordon Richards, Drexel Univ., June 13–July 19; Kate Rubin, Harvard-Smith., June 16–July 5; Frank van den Bosch, Yale Univ., June 17–Aug. 10; Greg Rudnick, Univ. Kansas, June 20–July 19; Julianne Dalcanton, Univ. Washington, June 23–July 25; Zeljko Ivezic, Univ. Washington, June 30–Aug. 31; Carmelo Arcidiacono, INAF, July 1–31; Alexia Lewis, Univ. Washington, July 1–Sep. 1; Dan Weisz, UC, Santa Cruz, July 1–Sep. 1; David Hogg, NYU, July 1–Aug. 30; Elisabeta Lusso, INAF, July 5–20; Daniel Foreman-Mackey, NYU, July 5–31; Karin Sandstrom, Univ. Arizona, July 7–Aug. 1; Vanja Sarkovic, University Belgrad, July 7–Sep. 14; Shirley Yancy, Steward Observatory, July 15–Dec. 15; Hongchi Wang, Purple Mt. Obs., July 21–Aug. 20; David Mykytyn, NYU, July 27–Aug. 15; Sandra Mitrovic, Univ. Sierre, Aug. 1–31; Ross Fadely, NYU, Aug. 6–22; Benjamin Weiner, Univ. Arizona, Aug. 7–27; Melih Ozcelik, University of Cambridge, Aug. 15–Sep. 26; Adam Stevens, Swinburne Univ., Aug. 17–30; Nicholas Hunt-Walker, Univ. Washington, Aug. 18–31; Kevin Croxall, OSU, Aug. 30–Sep. 27; J. D. Smith, Univ. Toledo, Sep. 15–Dec. 15; Nikolai Voshchinnikov, Univ. St. Petersburg, Sep. 18–Oct. 9; Anastasiia Bisiarina, Ural Fed. Univ., Sep. 29–Oct. 31; Javier Rodon, ESO, Oct. 26–Nov. 12; Laura Watkins, STScI, Oct. 26–Nov. 13; Brian Svoboda, Univ. Arizona, Nov. 22–Dec. 5; Sandra Mitrovic, Podgorica, Nov. 23–Dec. 24.

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

VI.3 Cooperation with External Companies

ADDITIVE GmbH, Friedrichsdorf
Adolf Pfeiffer GmbH, Mannheim
Aerotech GmbH, Nürnberg
Agilent Technologies, Böblingen
Alternate Computer Versand GmbH, Linden
Amphenol AIR LB GmbH, Saarlouis
ANDUS ELECTRONIC GMBH, Berlin
asknet AG, Karlsruhe
B.E.S.T., Forst
Baier Digitaldruck, Heidelberg
Bechtle ÖA direkt GmbH, Neckarsulm
BMW AG, München
Börsig GmbH, Neckarsulm
CADFEM GmbH, Grafing
Carl Roth GmbH & Co. KG, Karlsruhe
ColorDruck Solutions GmbH, Leimen
Computacenter AG & Co. oHG, Ludwigshafen
COMTRONIC GmbH, Heiligkreuzsteinach
Conrad Electronic GmbH, Wernberg-Köblitz
Cryophysics GmbH, Darmstadt
Dannewitz GmbH & Co, Gelnhausen
dataTec GmbH, Reutlingen
Dell GmbH, Frankfurt am Main
DeMaCo Holland B.V., Noord-Scharwoude
Digi-Key, Enschede
Distrelec Schuricht GmbH, Bremen
Dörfler Dachtechnik GmbH, Oftersheim
DPS Vakuum, Großrinderfeld
DPV Elektronik Service GmbH, Eppingen
DVS Dekont Vakuum Service GmbH, Erfurt
E. Theile Computer-Systeme GmbH, Speyer
EBSCO Information Services GmbH, Berlin
EDP Sciences, Les Ulis Cedex A France
Edwards GmbH, Kirchheim
ELMA Electronic GmbH, Pforzheim
esd electronic system design GmbH, Hannover
EUROstor GmbH, Filderstadt
Farnell GmbH, Oberhaching
Faulhaber GmbH & Co KG, Schönaich
Fels Fritz GmbH Fachspedition, Heidelberg
FlowCAD EDA-Software Vertrieb, Feldkirchen
Fraunhofer IOF, Jena
Geier Metall-u.Stahlhandel GmbH, Mannheim
Gleich Service-Center, Kaltenkirchen
Glenair Electronic GmbH, Bad Homburg
GSI Group Europe GmbH, Planegg
Häfele GmbH, Aulendorf
Hahn & Kolb, Ludwigsburg
Harald Tränkle GmbH, Heidelberg
HELUKABEL GmbH, Hemmingen
Hoffmann Group GmbH &Co.KG, Göppingen
Horn GMBH, Stutensee
Hositrad Deutschland, Regensburg
ICO Innovative Computer GmbH, Diez/Lahn
ILFA Feinstleitertechnik GmbH, Hannover
Ingenieurbüro Schlossmacher, Unterschleissheim
INNEO Solutions GmbH, Ellwangen
IOP Publishing Ltd., Bristol
Jacobi Eloxal GmbH, Altlussheim
Kai Ortlieb Buchbinderei, Eppelheim
Kniel GmbH, Karlsruhe
KOCO MOTION GmbH, Dauchingen
Konica Minolta Businesss, Mannheim
KORTH KRISTALLE GMBH, Altenholz
Laser Components, Olching
LASERVISION GmbH & Co.KG, Fürth
Lehmanns Fachbuchhandlung GmbH, Heidelberg
Leica Mikrosysteme Vertrieb Gm, Wetzlar
Lemo Elektronik GmbH, München
LYRECO Deutschland GmbH, Barsinghausen
Maschinenfabrik Berthold Hermle, Gosheim
Meilhaus Electronic GmbH, Alling
MEN Mikro Elektronik GmbH, Nürnberg
Metallbau GLAWION GmbH, Eberswalde
MICROSTAXX GmbH, München
National Instruments, München
Nature Publishing Group, London
Newport Spectra-Physics GmbH, Darmstadt
Nies Elektronic GmbH, Frankfurt
Oerlikon, Köln
PFEIFFER VACUUM GmbH, Asslar
Pfeiffer Vacuum GmbH, Wertheim
Physik Instrumente (PI), Karlsruhe
Phytron-Elektronik GmbH, Gröbenzell
Plano GmbH, Wetzlar
Polytec GmbH, Waldbronn
pro-com DATENSYSTEME GmbH, Eislingen
Profimess GmbH, Bremerhaven
Radiant Zemax Europe Ltd, Stansted
Reichelt Elektronik, Sande
Rhein Neckar BUSINESS Travel, Heidelberg
RS Components GmbH, Mörfelden-Walldorf
SAUTER-Cumulus GmbH, Freiburg
Schäfer-Shop GmbH, Betzdorf
Schroff GmbH, Straubenhardt
Sky Blue Microsystems GmbH, München
Storesys GmbH, Haan
Tautz Druckluft+Sandstrahltech, Mannheim
Telemeter Electronic GmbH, Donauwörth
The MathWorks GmbH, Ismaning
Theile Büro-Systeme, Speyer
Thermodyne GmbH, Osnabrück
Thorlabs GmbH, Dachau
Tydex J.S.Co, St. Petersburg
Witzenmann Rhein-Ruhr GmbH, Xanten

VI.4 Meetings and Talks

Meetings organized at MPIA:

Pan-STARRS1 KP5 Group Meeting, Mar. 3–5 (Martin, Rix)

Final MIDI Science Group Meeting, HdA, May 5–6 (Thomas Henning)

3D-HST team meeting, HdA, May 5–9 (van der Wel, Da Cunha)

Concluding MIDI Science Group Meeting, HdA, May 5–6 (Klaus Meisenheimer, Roy van Boekel)

Intergalactic Matters, HdA, June 16–20 (Hennawi, Arrigoni Battaia, Berner, Eilers, Farina, Khrykin, Kulkarni, Lee, Onorbe, Rorai, Schmidt, Sorini, Walther, Worseck)

Star Formation: Data, Models and Visualization, A Harvard-Heidelberg workshop, HdA, June 23–26 (Beuther, Robitaille, Henning, Johnston, Feng, Bihr, Morales)

MPIA-MPA workshop, June 24–26 (Stern)

Quenching and Quiescence – What slows down and stops star formation in Massive galaxies?, July 14–18 (Stinson, Dutton, Macciò)

Chemical Diagnostics in the ALMA/NOEMA Era, July 21–23 (Schinnerer, Semenov, Henning, Hughes, Querejeta)

Exoplanets with JWST – MIRI, HdA, Sep. 22–25 (Krause van Boekel, Bouwman, Henning, Scheerer, Scheithauer, Kopon)

LINC-NIRVANA Consortium Meeting, Oct. 22–23 (Kürster)

LINC-NIRVANA Science Team Meeting, Nov. 4 (Schinnerer, Norris)

Gaia Challenge 2014, HdA, Oct. 27–31 (van de Ven, Martig, Ness, Smith, Trick)

German-Japanese Meeting on Planet Formation, Detection and Characterization, HdA, Nov. 4–7 (Henning, Joergens, Kaltenegger, Klahr)

MPIA-Kuratorium, Dec. 2 (Jäger, Rix, Henning, Berner)

MPIA Science Day, Dec. 9 (Jäger, Krause, Venemans)

Other Conferences Organized or Supported:

American Astronomical Society Annual Winter Conference, National Harbor, Maryland, USA, Jan. 6–10 (Ho)

ARGOS wavefront sensor acceptance review, Florence OAA, Jan. 27–31 (Gässler)

Search for Life Beyond the Solar System: Exoplanets, Biosignatures & Instruments, Tucson, Arizona, USA, Mar. 16–21 (Kaltenegger)

Gaia and the unseen. The brown dwarf question, Torino, Mar. 24–26 (Bailer-Jones)

2nd Heidelberg-Oxford Milky Way workshop, Oxford, UK, Mar. 31–Apr. 2 (Rix)

LINC-NIRVANA Consortium Meeting, INAF Arcetri, Villa Galileo, Apr. 9–10 (Kürster)

MPIA External Retreat, Asselheim, May 12–13 (Jäger, Henning, Rix, Berner, Bader)

Herschel/PACS Photometer Working Group Meeting, KUL Leuven, Belgium, May 14 (Nielbock)

The Early Phase of Star Formation (EPOS) 2014, Schloss Ringberg, 1.–June 6 (Steinacker, Henning, Beuther, Linz, Nielbock, Ragan, Feng, Bihr)

Member of scientific organizing committee for the conference, Physics of Evolved Stars 2015, June 8–12 (Leinert)

Pan-STARRS1 collaboration meeting, STScI, Baltimore, USA, June 23–26 (Martin)

Astrophysical calibration of Gaia and other surveys, Schloss Ringberg, July 7–11 (Bailer-Jones, Rix, Smith)

Grain-Surface Networks and Data for Astrochemistry, Leiden, NL, July 28–Aug. 1 (Semenov)

Galactic Surveys and Suburbs workshop, Cambridge, UK, Aug. 28–31 (Bergemann)

Joseph von Fraunhofer – Der Ehrendoktor kam aus Erlangen, Arbeitskreis Astronomiegeschichte in der Astronomischen Gesellschaft, Bamberg, Sep. 22 (Lemke)

Frontiers of Stellar Structure and Evolution Heidelberg, IMPRS Summer School Sep. 22–26 (Fendt)

The Variable Sky: from Tiny Variations to Big Explosions, Tagung der AG, Bamberg, Sep. 22–26 (Jäger)

Public Outreach in der Astronomie, Bamberg, Sep. 24 (Jäger, Pössel)

Conference workshop: Accretion and Outflows throughout the scales: from young stellar objects to AGNs, Lyon, Oct. 1–3(Fendt)

Grenoble-Heidelberg Meeting on Star Formation, Schloss Ringberg Oct. 12–15 (Henning)

ISM-SPP Summer School 2014 - Laboratory Astrophysic, Tabarz, Oct. 13–17 (Henning, C. Jäger, Rouillé)

ISM-SPP Workshop 2014 - Laboratory Astrophysics, Tabarz, Oct. 16–18 (Henning, C. Jäger, Rouillé)

Gaia DPAC CU8 plenary meeting, Torino, Nov. 6–7 (Coryn Bailer-Jones)

MPIA-AIP Milky Way & Local Volume Meeting, Leibniz Institute for Astrophysics, Potsdam Nov. 11–12 (Ho)

PSF Retreat, Kloster Schöntal, Nov. 12–14 (van Boekel, Scheithauer, Berner)

Getting ready for Planetology beyond the Solar System, Schloss Ringberg, Nov. 17–21 (Mordasini, Miguel, Klahr, Kaltenegger)

International Santander summer school: Reaching the limits of the sky: astronomical instrumentation in the 21st century, Santiago de Chile, Nov. 17–28 (Henning, Gredel)

The Milky Way unravelled by Gaia: GREAT Science from the Gaia data releases, Barcelona, Dec. 1–5 (Bailer-Jones, Ho)

Herschel/PACS Photometer Working Group Meeting, MPE Garching, Dec. 2 (Nielbock)

The quest for Dark Energy II, Schloss Ringberg, Dec. 14–19 (Macciò, Penzo)

Invited talks and colloquia:

Fabrizio Arrigoni Battaia: ETH, Zürich, Schweiz, Nov. 27 (Talk); FLASH Seminar, UCSC, Santa Cruz, CA, USA, Nov. 14 (Kolloquium)

Tri L. Astraatmadja: Conference on Theoretical Physics and Nonlinear Phenomena (CTPNP): Neutrinos from GRBs and their detection with The ANTARES Neutrino Telescope, Universitas Sebelas Maret (UNS), Surakarta, Indonesien, Feb. 15 (Talk); Department of Physics, Universitas Gadjah Mada (UGM): High-energy astrophysics and multi-messenger astronomy, Jogjakarta, Indonesien, Feb. 18 (Colloquium)

Coryn Bailer-Jones: Gaia Challenge 2, HdA, MPIA, Okt. (Talk)

Maria Bergemann: Astrophysical calibration of Gaia and other surveys, Schloss Ringberg, July 7–11 (Talk); Frontiers of Stellar Structure and Evolution, Heidelberg, Sep. 22–26 (Talk); RASPUTIN: Resolved and unresolved stellar populations, Garching, Oct. 13–17 (Talk); Gaia

Challenge 2, Workshop, Heidelberg, Oct. 27–31 (Talk); Königstuhl Colloquium, MPIA, Nov. 7 (Colloquium)

Yan Betremieux: Exoplanets with JWST-MIRI: Effects of atmospheric refraction on exoplanet transmission spectra, HdA, MPIA, Heidelberg, Sep. 22 (Talk); German-Japanese meeting on planet formation, detection, and characterization: What role does exoatmospheric refraction play on exoplanet transmission spectra, HdA, MPIA, Heidelberg, Nov. 6 (Talk)

Henrik Beuther: Science with the Atacama Pathfinder Experiment: The carbon budget and formation signatures of molecular clouds at, Schloss Ringberg, Jan. (Talk); EPOS2014, Invited discussion lead about molecular clouds and turbulence, Schloss Ringberg, June (Talk); Chemical disgnaostics in the ALMA/NOEMA era: Chemistry in high-mass star formation, HdA, July (Talk); Galactic and extragalactic star formation: The HI/OH/Recombination line survey of the Milky Way, Marseille, Frankreich, Sep. (Talk); From Milky Way to small-scale structure: High-mass star formation, ETH, Zürich, Schweiz, Mar. (Colloquium); Prospects and future of observational ISM studies ISP-SPP school, Freising, May (Colloquium); Sternentstehung in der Milchstraße, Physikkolloquium an der Universität Mannheim, Dec. (Colloquium)

Wolfgang Brandner: MODEST 14: The dance of stars: dense stellar systems from infant to old, Bad Honnef, June 2–6 (Talk); Exoplanets with JWST – MIRI, Heidelberg, Sep. 22–25 (Talk); German-Japanese Exoplanet Conference, Heidelberg, Nov. 5–7 (Talk); HIRES2014: Astronomy at High Angular Resolution, Garching, Nov. 24–28 (Talk)

Roberto Decarli: 100th National Conference of the Italian Physics Society, Pisa, Italien, Sep. 22–26 (Talk); Role of Hydrogen in the Evolution of Galaxies, Kuching, Malaysia, Sep. 15–19 (Talk); Albert Einstein Institut, Golm, June 17 (Talk); Osservatorio Astronomico di Bologna, Italien, Apr. 17 (Talk)

Aaron Dutton: Galaxy Masses as Constraints to Formation Models: Scaling relations of late-type galaxies, Oxford, Großbritannien, July (Review); Quenching and Quiescence, The Stellar Initial Mass Function of Massive Galaxies, Heidelberg, July

Nikos Fanidakis: SAM models and hydrodynamic simulations, Marseille, Frankreich, June (Talk); MPIA-MPA Theory Workshop, Heidelberg, June (Talk); Quenching and Quiescence, Heidelberg, July (Talk); Clustering Measurements of AGN, ESO, Garching, July (Talk); Konferenz AGN vs. SF, Durham, Großbritannien, July (Talk); ESO, Garching, Mar. (Colloquium); Durham University, Durham, Großbritannien, Apr. (Colloquium); Universität Zürich, Schweiz, (Colloquium); AIP, Potsdam, Okt. (Colloquium)

Christian Fendt: ISSI Workshop, The Strongest Magnetic Fields in the Universe, International Space Science Institute (ISSI), Bern, Schweiz, Feb. 3–7 (Talk); The early phase of star formation (EPoS), Schloss Ringberg, June 1–6 (Talk); Conference workshop, Accretion and Outflows throughout the scales: from young stellar objects to AGNs, Ecole Normale Superieure de Lyon, Frankreich, Oct. 1–3 (Talk)

Carl Ferkinhoff: MPIA, Heidelberg, May 30 (Colloquium)

Daniele Fulvio: Summer school »Laboratory Astrophysics«: Radiation-Induced Processing at the Interface Ice/Dust Grains, Tabarz, Oct. 13–16 (Tutorial); The conundrum of the missing silicon carbide (SiC), Laboratory for Experimental Astrophysics Group in Catania, INAF – OACT, Italien, Sep. 3 (Talk); A straightforward method for VUV flux measurements: The case of the H2 discharge lamp and implications for solid-phase actinometry, Laboratory for Experimental Astrophysics Group in Catania, INAF – OACT, Italien, Sep. 1 (Talk)

Roland Gredel: C60 and its relation to the diffuse interstellar bands, Institut für Festkörperphysik, Jena, Feb. 13 (Talk); Lowell Observatory, Flagstaff, Arizona, USA: The mystery of the diffuse interstellar bands, Mar. 26 (Talk); ISM-SPP summer school on laboratory astrophysics: The interstellar gas phase, Tabarz, Oct. 14 (Talk); The European Extremely Large Telescope, Santander School, Santiago de Chile, Chile, Nov. 18 (Talk)

Thomas Henning: ESO, Santiago de Chile, Feb. 6 (Colloquium); Universidad de Chile, Santiago de Chile, Chile, Mar. 13 (Colloquium); Pontifica Universidad Católica, Santiago de Chile, Chile, Apr. 1 (Colloquium); Herbig Ae/Be Stars, Santiago de Chile, Chile, Apr. 7–11 (Talk); Universidad de Valparaiso, Chile, Chile, Apr. 15 (Colloquium); Early Phases of Star Formation, Schloss Ringberg, June 2–6 (Talk); Harvard-Heidelberg Meeting, Heidelberg, June 23–26 (Talk); JWST GTO Team Meeting, Baltimore, Maryland, USA, Aug. 6–7 (Talk); MPIA / IPAG, Grenoble Heidelberg Meeting, Schloss Ringberg, 12.–15. Okt (Talk); Marker Lectures Pennsylvania State University, Pennsylvania, USA, Oct. 20–23 (Talk); Symposium, Santander Summer School on Astronomical Instrumentation, Santiago de Chile, Chile, Nov. 27–28 (Talk)

Tom Herbst: Reaching the Limits of the Infrared Sky, Santander Summer School, Santiago de Chile, Chile, Nov. 18 (Talk); Natural Limits to Infrared Observations Sky, Santander Summer School, Santiago de Chile, Chile, Nov. 19 (Talk); Infrared Telescopes, Instrumentation, and Detectors Sky, Santander Summer School, Santiago de Chile, Chile, Nov. 19 (Talk); High Spatial Resolution Astrophysics with LINC-NIRVANA, Santander Summer School, Santiago de Chile, Chile, Nov. 24 (Talk)

Stefan Hippler: Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, Shanghai, China, May 8 (Talk); Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, Shanghai, China, Dec. 3 (Talk)

Cornelia Jäger: Cosmic dust in the laboratory: From Molecules to Solids, International Workshop on Astromineralogy II, Research Center for Astronomy and Earth Sciences, Budapest, Ungarn, Sep. 29–30 (Talk); Viki Joergens: European Southern Observatory, Garching, Oct. 14 (Colloquium); Arcetri Observatory, Florenz, Italien, May 22 (Colloquium); German-Japanese Meeting on Planet Formation, Detection and Characterization, MPIA/HdA, Heidelberg, Nov. 4–7 (Talk)

Hubert Klahr: Exo-planets and Planetology: Planetesimal Formation, Schloss Ringberg, Nov. (Talk); Workshop III: Geophysical and Astrophysical Turbulence, Linear stability of accretion disks under the influence of stratification and thermal relaxation, IPAM, UCLA, Kalifornien, USA, Okt. (Talk); Planet Formation and Evolution 2014: Planet-Disk interaction, Universität Kiel, Sep. (Übersichtsvortrag); Non-ideal MHD, Stability, and Dissipation in Protoplanetary Disks: Linear stability of accretion disks under the influence of stratification and thermal relaxation, Niels Bohr Institut, Kopenhagen, Dänemark, Aug. (Talk); From the MRI to the Sun: a conference to celebrate the 60th birthday of Steven Balbus, Hydrodynamic Stability of Disks, Chamonix, Frankreich, July (Talk); Zonal Flows and Vortices in Circumstellar Disks: The

Formation of Planetesimals in Starving Mode, ITC, Harvard, May (Colloquium); The Formation of Planetesimals in Starving Mode: Zonal Flows and Vortices in Circumstellar Disks, Schloss Ringberg, Nov. (Talk)

Zonal Flows and Vortices in Circumstellar Disks: The Formation of Planetesimals in Starving Mode, University of Michigan, Mar. (Colloquium); Zonal Flows and Vortices in Circumstellar Disks: The Formation of Planetesimals in Starving Mode, University of Chicago, Mar. (Colloquium); From nucleosynthesis to first planets, Michigan State University, Mar. (Colloquium)

Rainer Köhler: Infrared Interferometry of Young Stars and their Disks, Hamburger Sternwarte, Sep. 3 (Colloquium)

Christine Maria Köpferl: Reality Check: Gauging techniques which trace star formation, MPA, München: Dec. 3 (Talk)

Serge A. Krasnokutski: Summer school Laboratory Astrophysics: Cryochemistry in the Inert and Interstellar Media, Tabarz, Oct. 13–16 (Tutorial)

Oliver Krause: Far-Infrared Interferometer Workshop: The JWST-MIRI instrument, Rom, Italien, Feb. 17–18 (Talk)

Kathryn Kreckel: The Zeldovich Universe: Genesis and Growth of the Cosmic Web, Tallinn, Estland, June 23–28 (Talk); 3D2014: Gas and stars in galaxies: A multi-wavelength 3D perspective, Garching, Mar. 10–14 (Talk)

Rolf Kuiper: Fire Down Below – The Impact of Feedback on Star and Galaxy Formation, Kavli Institute for Theoretical Physics, Santa Barbara, Kalifornien, USA, Apr. 17 (Talk)

Khee-Gan Lee: Intergalactic Matters, MPIA, Heidelberg, June 16–20 (Talk); Exploiting VST Atlas and its Sister Surveys, Durham, Großbritannien, Apr. 14–16 (Talk)

Dietrich Lemke: Max Wolf – Stammvater der Heidelberger Astronomie, Planetarium Mannheim, Jan. 15 (Talk); Max Wolf – Wegbereiter der Himmelsfotografie und Stammvater der Heidelberger Astronomie, Sternwarte Starkenburg, Heppenheim, Dec. 9 (Talk); Kleinplanetentagung: Max Wolf und die Heidelberger Astronomie-Geschichte, MPIA/HdA, Heidelberg, June 14 (Colloquium)

Hendrik Linz: Cosmic Dust – An Observer's Tale, ISM-SPP School, Laboratory Astrophysics, Tabartz, Oct. 13–17 (Talk)

Luigi Mancini: Towards Other Earths II: The Star-Planet Connection: Photometric follow-up of transiting exoplanets with ground-based medium-class telescopes, Oporto, Portugal, Sep. 15–19 (Talk); Exoplanets with JWST – MIRI: Studying transiting exoplanets with ground-based medium-class telecopes, MPIA/HdA, Heidelberg, Sep. 22–25 (Talk); 5th GAPS Progress Meeting: Photometric follow-up of planetary transits from Loiano and Calar Alto, Astronomical Observatory of Capodimonte, Napoli, Italien, Oct. 22–24 (Talk); Exo-Planets and their Formation: Photometric follow-ups of transiting exoplanets with ground-based medium-class telecopes, MPIA/HdA, Heidelberg, Nov. 4–7 (Talk); Getting ready for Planetology beyond the Solar System: Accurate properties of extrasolar planets from observations of transit events, Schloss Ringberg, Nov. 17–11 (Talk); Astrophysical Observatory of Turin, Accurate characterisation of transiting exoplanets by photometric follow-up observations, Turin, Italien, Nov. 27 (Colloquium)

Gabriel-Dominique Marleau: Planet Formation and Evolution 2014: Population synthesis, Kiel, Sep. 8–10

Marie Martig: Quenching and Quiescence, Heidelberg, July 14–18 (Talk); Decoding the Assembly History of Galaxies, Leiden, Oct. 20–24 (Talk); AIP, Potsdam, Apr. 8 (Colloquium)

Nicolas Martin: University of Irvine, Irvine, USA, Feb. 11 (Colloquium); IRAM & LAOG, Grenoble, Frankreich, Apr. 24 (Colloquium); Observatoire de la Côte d'Azur, Nizza, Frankreich, July 1 (Colloquium); Institute of Astronomy, Cambridge, Großbritannien, Sep. 3 (Colloquium); Observatoire de Besançon, Besançon, Frankreich, Sep. 16 (Colloquium); Gutenberg Astrophysics work-shop & winter school, ècole, Straßburg, Frankreich, Jan. 14 (Talk); Journèes Grands Relevès PNCG, Paris, Frankreich, Apr. 28 (Talk); Atelier NSLS aux journèes de la SF2A, Paris, Frankreich, June 2 (Talk); Pan-STARRS1 Science Consortium meeting, Baltimore, USA, June 25 (Talk); 11th Potsdam thinkshop: Satellite galaxies and dwarfs in the Local Group, Aug. 25 (Talk); Journèes Nationales du PNCG, Paris, Frankreich, Nov. 26 (Talk); Sharon E. Meidt: Keck Institute for Space Studies workshop, Bridging the Gap, California Institute of Technology, Pasadena, CA, Nov. (Talk); The Role of Hydrogen in Galaxy Evolution, Kuching, Malaysia, Sep. (Talk); 3rd annual MPIA summer conference, Quenching and Quiescence, Heidelberg, July (Talk); European Week of Astronomy and Space Science (EWASS) 2014, Submm astronomy in the ALMA era, Genf, Schweiz, June (Talk); Heidelberg-Harvard 2014 workshop, Star Formation: data, models and visualization, MPIA, Heidelberg, May (Talk); Paul Mollière: Towards Other Earths II: The Star-Planet Connection conference in Porto: Models of Planet Formation, Portugal, Sep. 18 (Talk); Linking the planetß formation history to its present-day composition, The Disk in Relation to the Formation of Planets and their Protoatmospheres, ISSI-BJ/ISSI workshop in Beijing, China, Aug. 26 (Talk)

Melissa Ness: SDSS Collaboration Meetings, Park City, Utah, USA from July 26–30 (Colloquium); LAM, Marseille, Frankreich, Mar. 14; UCLAN, Großbritannien, Jan. 29 (Colloquium)

Nadine Neumayer: The Unquiet Universe: Nuclear star clusters and black holes, Cefalù, Italien, June 5–8 (Talk); Lorentz Centre workshop, Nuclear Clusters in Galaxies: Black Holes in Nuclear Star Custers, Leiden, June 30–July 4 (Talk); Heidelberg Joint Astronomical Colloquium, Universität Heidelberg, Nov. 4 (Colloquium)

Johan Olofsson: Cosmic Dust, Sangyo University, Osaka, Japan, Aug. 4–8 (Talk)

Camilla Penzo: Paris Observatory, Meudon, Frankreich, Nov. 27 (Talk)

Hans-Walter Rix: PanSTARRS maps the Milky Way, AIP Conference on the Local Group, Aug. 25 (Talk); Towards Estimating Stellar Ages, Ringberg Workshop in Precision Stellar Measuremens in the Age of Gaia, July 20 (Talk); Dynamical Modelling of the Galactic Disk, Gaia Conference, Barcelona, Spanien, Dec. 4 (Talk); The Assembly of the Milky Way, IPP, Garching, Mar. 14 (Colloquium); The Galactic Disk, Seminar Cambridge, Nov. 17 (Colloquium)

Gael Rouillé: Summer school Laboratory Astrophysics: Molecules and UV/vis Photons – From the ISM to the Laboratory, Tabarz, Oct. 13–16 (Tutorial); Formation of silicates in the interstellar medium: Laboratory experiments Seminaires du Laboratoire d'Astrophysique de Bordeaux, Observatoire de Bordeaux, France, Apr. 20 (Seminar)

Eva Schinnerer: Impact of Galactic Structure on Star Formation, Sapporo, Japan, Feb. (Talk); Leiden Observatory, Leiden, Niederlande (Colloquium); ESO/MPE/MPA, ESO, Garching (Colloquium); Symposium Galaxies in 3D across the universe, Wien, Österreich, July (Talk); AG Tagung, Splinter Meeting »LOFAR & SKA Science«, Bamberg, Sep. (Talk)

Eddie Schlafly: Dust with Gaia, Schloss Ringberg, July 10 (Talk)

Dmitry Semenov: Ural Federal State University, Astronomy Department, Yekaterinburg, Russlland, May 27 (Colloquium); SRON, Groningen, Niederlande, June 18 (Colloquium); Grain-Surface Networks and Data for Astrochemistry, Leiden, Niederlande, July 28 (Talk)

Robert Singh: Quenching and Quiescence, MPIA, Heidelberg, July 17 (Talk)

Kester Smith: Astrophysical calibration of Gaia and other surveys (GaiaCal 2014): Apsis: the Gaia astrophysical parameter inference system, Schloss Ringberg, July 7–11 (Talk)

Jürgen Steinacker: The Early Phase of Star Formation, Schloss Ringberg, June 5 (Talk)

Jonathan Stern: Nicolaus Copernicus Astronomical Center, Warschau. Polen, Dec. 3 (Colloquium); Observatoire astronomique de Straßburg, Frankreich, Dec. 5 (Colloquium)

Greg Stinson: From Dark Matter to Galaxies, Xiän, China, May (Talk); Driving Galactic Outflows in Simulations, Simons Workshop on Galactic Outflows, Puerto Rico, Mar. (Talk); Astrophysics Seminar, University of Washington, Washington, USA, Dec. (Colloquium); Astrophysics Seminar, University of Utah, Salt Lake City, Utah, Dec. (Colloquium); Lunch Talk, Carnegie Observatories, Pasadena, Kalifornien, Dec. (Colloquium); Center for Astrophysics and Space Science Seminar, UC San Diego, Kalifornien, USA, Dec. (Colloquium); Astrophysics Seminar, UC Irvine, Kalifornien, USA, Dec. (Colloquium); FLASH Lunch Talk, UC Santa Cruz, Kalifornien, USA, Dec. (Colloquium); Theoretical Astrophysics Center Lunch talk, UC Berkeley, Kalifornien, USA, Dec. (Colloquium); University of Massachusetts, Amherst, USA, Okt. (Colloquium); YCAA Seminar, Yale University, New Haven, Connecticut, USA, Okt. (Colloquium); Astronomy Seminar, Boston University, Boston, Massachusetts, Okt. (Colloquium); Astrophysics Seminar, Columbia University, New York, New York, Okt. (Colloquium); Astro Tuesdays, Rutgers University, Newark, New Jersey, Okt. (Colloquium); Königstuhl Colloquium, MPIA, Aug. (Colloquium); Galaxy Seminar, Oxford University, Oxford, Großbritannien, June (Colloquium); Monday Afternoon Seminar, University of Exeter, Großbritannien, June (Colloquium); Friday Afternoon Seminar, Royal Observatory, Edinburgh, Großbritannien, June (Colloquium); Amelia Stutz: Sexten Meeting: Mass assembly from clouds to clusters, Sexten, Italien, July 7–11 (Talk)

Richard Teague: Chemical Diagnostics of Star and Planet Formation with ALMA Cycle 3, MPE, Garching, Jan. 13–15 (Talk)

Roy van Boekel: Herbig AeBe stars – the missing link in star formation: Dust processing in Herbig Ae star disks, Santiago de Chile, Chile, Apr. 7–11 (Talk), Spectral diagnostics of formation history in hot Jupiter atmospheres, Nanjing University, China, May 15 (Colloquium)

Glenn van de Ven: IAU symposium 309, Galaxies in 3D across the Universe, Wien, Österreich, July (Talk); Nuclear Clusters in Galaxies, and the Role of the Environment, Lorentz Center, Leiden, Niederlande, July (Talk); University of Straßburg, Straßburg, Frankreich, Apr. (Colloquium); 3D2014: Gas and stars in galaxies: A multi-wavelength 3D perspective, ESO, Garching, Mar. (Talk); Max-Planck-Institut für Kernphysics (MPIK), Heidelberg, Jan. (Colloquium)

Arjen van der Wel: Marie Curie INT DAGAL/S4G meeting, Leiden Observatory, Niederlande, Oct. 20–24 (Talk); Quenching and Quiescent, MPIA, Heidelberg, July 14–18 (Talk)

Fabian Walter: The Formation and Growth of Galaxies in the Young Universe, Obergurgl, Apr. 29 (Talk); Edinburgh, Großbritannien, Jan. 22 (Colloquium); The first billion years of galaxies and black holes, Sexten, Italien, June 1 (Talk); Hertforshire, Großbritannien, Dec. 3 (Colloquium)

Gabor Worseck: Intergalactic Matters, MPIA, Heidelberg, June 16–20 (Talk); Exploiting VST Atlas and its Sister Surveys, Durham, Großbritannien, Apr. 14–16 (Talk)

Svitlana Zhukovska: SFB 956, Physikalische Institute, Köln, Oct. 6 (Colloquium); Invited Lecture at KROME summer school, Göttingen, Sep. 19 (Talk); Iowa State University, Ames, Iowa, USA, May 9 (Colloquium)

Lecture series:

Coryn Bailer-Jones: Summer School in Statistics for Astronomers IX, Pennsylvania State University, Pennsylvania, USA, June 3–7

Wolfgang Brandner: Exoplaneten (Teacher training), Sternwarte Sonneberg, Germany, Sep. 16–17

Popular science talks:

Coryn Bailer-Jones: Gaia Live Event, Hebel Gymnasium, Schwetzingen, Mar.

Roland Gredel: Homenaje a Dr. Kurt Birkle, Escuela Municipal de Musica y Artes, Almeria, Spanien, May 28

Richard Hanson: ESA GaiaLive in Schools, Hebel-Gymnasium Schwetzingen, Mar. 25

Thomas Henning: Penn State University, Oct. 21; Sternwarte Starkenburg, Heppenheim, Okt.; Planetarium, Santiago de Chile, Nov. 26

Tom Herbst: From Galileo to the European ELT: Building the Biggest Telescope in the World, MPIA Heidelberg, May 7

Stefan Hippler: Der scharfe Blick ins Universum. Laser und Adaptive Optik ermöglichen glasklare Sicht ins All. Robert-Mayer-Sternwarte, Heilbronn, Jan. 24; Der scharfe Blick ins Universum. Laser und Adaptive Optik ermöglichen glasklare Sicht ins All. Planetarium Mannheim, Mar. 19; Das Europäische Extremely Large Telescope und seine »Ersten« Instrumentierungen. Print Media Academy, Heidelberg, Oct. 15

Klaus Jäger: GirlsDay: Der Himmel im Computer zuhause – Virtuelle Planetarien, MPIA/HdA, Mar. 27.; Science at MPIA, International Summer Science School Heidelberg, MPIA/HdA, Heidelberg, June 31; Science at MPIA, International Conference of Physics Students Heidelberg, MPIA/HdA, Heidelberg, Aug. 15; Das Unsichtbare sichtbar machen – Highlights aus der (Heidelberger) Trickkiste astronomischer Beobachtungen, Tagung der Vorstände der Volksbanken, MPIA/HdA, Heidelberg, Sep. 6; Welche Bedeutung hat die Astronomie?, Festrede zum 100-jährigen Jubiläum der Robert-Mayer-Sternwarte Heilbronn, Bildungscampus Heilbronn, Sep. 19; Scharfblick, Weitsicht, Zeitmaschine – 400 Jahre Astronomie mit dem Fernrohr, Festvortrag zum 100-jährigen Jubiläum der Robert-Mayer-Sternwarte Heilbronn, Bildungscampus Heilbronn, Sep. 19; Wissenschaft am MPIA, Tagung der Fachkräfte für Arbeitssicherheit, MPIA/HdA, Sep. 30; Die Vermessung der Welt – Wie Astronomen Entfernungen im All bestimmen, Pfalzmuseum für Naturkunde, Bad Dürkheim, 2. Okt; Galaxien und Terabytes – Astronomie mit modernen Großteleskopen, Schülerpraktikum Astronomie (SchüPA) 2014, HdA/MPIA, Oct. 20; Der lange Weg zu den Galaxien – Entfernungsbestimmung in der Astronomie, Universität Göttingen, Förderkreis Planetarium Göttingen, Oct. 21

Knud Jahnke: Schwarze Löcher, Haus der Astronomie, Heidelberg, Okt.; Structure formation in the Universe since the Big Bang: an introduction, Japanese-German Frontiers of Science Symposium, Bremen, Nov.; Der Stand der Dinge: Galaxien 2014, Haus der Astronomie, Heidelberg, Nov. 13

Viki Joergens: Wie entstehen freifliegende Planeten und Braune Zwerge?, Ministerium für Wissenschaft, Forschung und Kunst Baden-Württemberg, Stuttgart, Germany, Mar. 19

Hubert Klahr: Astronomie am Sonntag Vormittag: Die Geburt der Planeten: Neueste Erkenntnisse zur Entstehung von Planetensystem, HdA/MPIA, Sep.; LeLa-Jahrestagung: Auf der Suche nach der zweiten Erde, Heidelberg, Mar.

Christine Maria Köpferl: Augustinum Heidelberg: More than just a glimpse to the stars, HdA

Oliver Krause: Das James-Webb-Weltraumteleskop: Ein neues Fenster zum infraroten Kosmos, Planetarium Laupheim, May 23

Martin Kürster: Wie groß ist das Universum?, Planetarium Mannheim, Oct. 1

Ralf Launhardt: Das wechselhafte Leben der Sterne, HdA, Mar. 21 und Apr. 29; Der Lebensweg der Sterne, Rüsselsheimer Sternfreunde, Rüsselsheim, Oct. 17

Dietrich Lemke: Joseph von Fraunhofer – Der Ehrendoktor kam aus Erlangen, Arbeitskreis Astronomiegeschichte in der Astronomischen Gesellschaft, Bamberg, Sep. 22

Hendrik Linz: Von Herschel zu James Webb: Weltraumteleskope heute und morgen, Lehrerfortbildung Astronomie, Friedrich-Schiller-Universität Jena, July 21–23

Nadine Neumayer: Wissenschaft für jedermann: Giganten der Schwerkraft: Schwarze Loecher in den Zentren von Galaxien, Deutsches Museum, München, Feb.

Markus Nielbock: Kalte und dunkle Kinderstuben im All, Erkenntnisse des Weltraumteleskops Herschel Über die Geburt der Sterne, Westfälische Volkssternwarte und Planetarium Recklinghausen, Feb. 12; Faszination Astronomie, Dunkelwolken – Frostige Kinderstuben der Sterne, HdA, Heidelberg, Sep. 11 (Talk)

Hans-Walter Rix: Wie baut man eine Milchstraße? Volkssternwarte Darmstadt, Mar. 22; Wie das Universum interessant wurde. Schülerakademie, Regensburg, Sep. 26

Fabian Walter: ALMA, HdA, May 9; ALMA: Neue Einblicke in das dunkle Universum, Fachhochschule Mannheim, Mar. 21

VI. 5 Teaching and Service

Lectures, seminars, tutorials etc.

Winter Term 2013/2014:

Fabrizio Arrigoni Battaia: F30 Stellare CCD-Photometrie (Tutorial)

Tri L. Astraatmadja: High-energy astrophysics and multimessenger astronomy, School of Advanced Physics, Universitas Gadjah Mada, Jogjakarta, Indonesia (Advanced seminar)

Coryn Bailer-Jones: Experimental Physics 3 (Bachelor course)

Maria Bergemann: Experimental Physics 1 (PEP1) (Tutorial)

Maria Bergemann: Topics in Modern Astrophysics, University of Cambridge (Tutorial)

Henrik Beuther: Einführung in die Astronomie und Astrophysik I (Lecture)

Henrik Beuther: Königstuhl Colloquium (Colloquium)

Christian Fendt: Einführung in die Astronomie und Astrophysik I, Universität Heidelberg (Lecture)

Christian Fendt: Current research topics (IMPRS 1) (Advanced seminar)

Thomas Henning: Physics of Star Formation (Advanced seminar)

Anna Ho: Introduction to Cosmology. Hands-On Science! MIT Educational Studies Program (Course, jointly with Camilla Penzo)

Cornelia Jäger: Laboratory Astrophysics (Seminar, jointly with H. Mutschke, University Jena, Institute of Solid State Physics)

Knud Jahnke: Planeten- und Sternentstehung, (Obligatory bachelor seminar, jointly with Kees Dullemond (ZAH/ITA))

Viki Joergens: Übungen zur Experimentalphysik 1, Klassische Mechanik (Tutorial)

Hubert Klahr: Fundamentals of Simulation Methods (Lecture, jointly with K. Dullemond, ZAH/ITA)

Hubert Klahr, Coryn Bailer-Jones: Introduction to Astronomy and Astrophysics III (Seminar)

Hubert Klahr: UKNum – Lecture and Lab-work on numerical Physics (Lecture with exercises)

Andrea Macciò: Galaxies (Lecture, jointly with Glenn van de Ven)

Andrea Macciò: Galaxy formation (Lecture)

Klaus Meisenheimer: IMPRS (Seminar)

Dmitry Semenov: Molecular Astrophysics: from Theory to Lab to Observations (Lecture series)

Glenn van de Ven, Andrea Macciò: Galaxies (Block course with exercises)

Michael Walther: Cosmology (Tutorial)

Summer Term 2014

Coryn Bailer-Jones: Experimentalphysik 2 (Bachelor course)

Henrik Beuther: Einführung in die Astronomie und Astrophysik III (Bachelor seminar)

Henrik Beuther: Königstuhl Colloquium (Colloquium)

Christian Fendt, Glenn van de Ven, Joe Hennawi: IMPRS Seminar 2 (Seminar)

Christian Fendt: Current research topics (IMPRS 1) (Seminar)

Christian Fendt: Übungen zur Experimentalphysik II (Tutorial)

Thomas Henning: Physics of Star Formation (Advanced seminar)
Cornelia Jäger: Laboratory Astrophysics (Lecture, jointly with Übungen, together with H. Mutschke, H. Walter, University Jena, Institute of Solid State Physics)
Knud Jahnke, Hans-Walter Rix: Einführung in die Astronomie und Astrophysik II (Lecture)
Viki Joergens: Ultracool objects (Obligatory master seminar)
Glenn van de Ven: Unsere Milchstraße und Galaxien (Pflichtseminar together with Andreas Just (ZAH/ARI))
Christine Maria Köpferl: Python for Scientists (Tutorial)
Klaus Meisenheimer: Übungsgruppe für PEP2 (Tutorial)
Reinhard Mundt: Einführung in die Astronomie und Astrophysik III (Lecture)
Thomas Robitaille: Programming for Scientists (Block course)

Winter Term 2014/2015

Knud Jahnke: Galaxienhaufen (Obligatory bachelor seminar, jointly with Thorsten Lisker (ZAH/ARI))
Coryn Bailer-Jones: Introduction to Astronomy & Astrophysics 3 (Obligatory bachelor seminar)
Henrik Beuther: Königstuhl Colloquium (Colloquium)
Henrik Beuther: Protostars and Planets (Master seminar)
Christian Fendt: Current research topics (IMPRS 1) (Advanced seminar)
Christian Fendt: Übungen zur Experimentalphysik I (Tutorial)
Thomas Henning: Physics of Star Formation (Advanced seminar)
Cornelia Jäger: »Processing of grains« und »Synthesis of cosmic dust analogs and Processing of grains«, summer school »Laboratory Astrophysics«, Tabarz, Oct. 13–16 (Block seminars)
Viki Joergens, Henrik Beuther: Protostars and Planets (Obligatory master seminar)
Christine Maria Köpferl: Python for Scientists (Tutorial)
Andrea Macciò: Galaxy formation (Lecture)
Klaus Meisenheimer: IMPRS (Seminar)
Klaus Meisenheimer: Heraeus School, Padua (Compact lecture series)
Paul Mollière: Fundamentals of Simulation Methods (Tutorial)
Thomas Robitaille: Programming for Scientists (Block course)
Dmitry Semenov: Kleine Körper des Sonnensystems (Obligatory master seminar)
Athanasia Tsatsi: Astro Lab (Tutorial)
Glenn van de Ven, Andrea Macciò: Galaxies (Block course with exercises)
Glenn van de Ven, Elisabete da Cunha, Fabrizio Arrigoni Battaia: Galaxy Coffee (Seminar)
Michael Walther: Cosmology (Tutorial)

Membership in major committees

Coryn Bailer-Jones: Astrophysical Parameters (CU8) in the Gaia Data Processing and Analysis Consortium (Sub-consortium manager); Gaia Data Processing and Analysis Consortium Executive (Member)
Maria Bergemann: Panel D of the ESO OPC for P95 (Member)
Henrik Beuther: IRAM program committee (Chair of the Galactic Panel); APEX program committee (Member); German SOFIA Science Working Group (Member)
Wolfgang Brandner: SPHERE Editorial Board (Member), PS1 Scientific Council (Member), Hungarian Scientific Research Fund (OTKA) (Member), European Commission (FP7, Horizon 2020) (Member), ESO OPC (Leiter 2012–2014)
Christian Fendt: DAAD-Auswahlkomission »Programm zur Förderung ausländischer Doktoranden« (Member), L'Agence Nationale de la Recherche (ANR) (Referee), Alexander von Humbolt Stiftung (Referee), IUF – Institut universitaire de France (Referee)
Bertrand Goldman: Science Policy Oversight Committee of the PanSTARRS1 consortium (Chair)
Roland Gredel: ELT Project Science Team (Member); CTA site selection committee (Member), LBT scientific advisory committee (Member), Opticon board (Chair)
Thomas Henning: Vorsitzender des Astronomy Panel der Akademie Leopoldina; ESO Council (Member); Fachbeirat der Thüringer Landessternwarte Tautenburg (Member); Fachbeirat des Hungarian Research Centre for Astronomy and Earth Sciences (Member); Komitee des Stern-Gerlach-Preises der DPG (Member); Direktor-Berufungskomitee des MPE (Member); Auswahlkomitee der MPG Research Groups (Member); ERC Advanced Grants, Universe Science (Co-chair)
Tom Herbst: LBT Science Advisory Committee (Member), EELT Project Science Team (Member), NOVA Instrument Steering Committee (Member)
Cornelia Jäger: Gutachter für die DFG; Mitglied des Gremiums des DFG Priority Program »The Physics of the Interstellar Medium«
Klaus Jäger: Pressereferent der Astronomischen Gesellschaft; Vertreter der MPIA-InstitutsHead beim Rat Deutscher Sternwarten (RDS); International Summer Science School Heidelberg (Beirat); Arbeitskreis Wissenschaftsmarketing der Stadt Heidelberg (Member); Förderverein des Haus der Astronomie (2. Vorsitzender)
Knud Jahnke: Euclid Consortium Coordination Group, Euclid NISP Instrument System Team, Euclid Membership Committee, Euclid Calibration Working Group (jeweils Mitglied); Alexander von Humboldt Japanese-German Frontiers of Science Symposium 2014 + 2015 (Mitglied der Planungsgruppe)
Viki Joergens: Gutachter für die DFG
Ulrich Klaas: Mitglied des Gremiums für den unabhängigen Euclid Calibration Review
Rainer Köhler: ESO Observing Programme Committee (Member)
Ralf Launhardt: ERC starting grants PE9 (Member)
Dietrich Lemke: Time Allocation Committee für Beobachtungen mit dem Flugzeugobservatoriums SOFIA (Chair)
Nicolas Martin: Pan-STARRS1 Science Council (Member), Strasbourg board of Physics Graduate Studies (Member)
Klaus Meisenheimer: DFG (Referee); Graduate Women in Science fellowship (Member); LINC-NIRVANA (Member)
Reinhard Mundt: CARMENES Core Management Team (Member)
Nadine Neumayer: Research Board of the Excellence Cluster Universe (Member), Garching; ESO Fellow selection committee (Member)
Markus Nielbock: SOFIA German TAC for Cycle 3 Observations (Member); Herschel Calibration Steering Group (Member); Herschel/PACS Photometer Working Group (Chair)
Johan Olofsson: ESO OPC for periods P94 and P95 (Member)
Hans-Walter Rix: ESA Space Science Advisory Committee (Member); ESO Visiting Committee (Member); Euclid-Board (Member); STScI Visiting Committee (Member); NOVA Visiting Committee

(Member); SDSS-IV Review Committee (Member); CAHA Executive Council (Member); LBTB Gesellschafterversammlung (Chair); LBTC Board (Vertreter der LBTB-Mitglieder); Alexander von Humboldt Foundation (Mitglied des Auswahlkomitees)

Eva Schinnerer: NRAO Users Committee (Member); ESO STC subcommittee ESAC (Member)

Dmitry Semenov: NASA Exoplanet Review Panel (external member)

Roy van Boekel: Belgian VLTI TAC (Member)

Arjen van der Wel: International CAHA Time Allocation Committee (Chair)

Svitlana Zhukovska: Evaluation committee of NASA Astrophysics Data Analysis Program (Member)

VI. 6 Haus der Astronomie

Haus der Astronomie, literally "House of Astronomy" (HdA), is a center for astronomy education and outreach on the 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 has constructed custom-designed, galaxy-shaped building for the endeavour and, in addition, donated the building's basic equipment. The Max Planck Society is responsible for operating the center, a task it has delegated to the Max Planck Institute for Astronomy (MPIA)

The HdA's mission is to demonstrate to the public in general, and to young people in particular, the fascination of astronomy, and to further the communication between astronomers and their colleagues in other scientific disciplines. To this end, we organize events for the general public, and workshops for students, teachers, and communicators; we support research projects undertaken by high school students, participate in exhibitions, develop astronomy kits, visualizations of astronomical phenomena and concepts, and support the media in their coverage of astronomical topics.

Managing Scientist: Markus Pössel

Organisational assistance: Sigrid Brümmer

Outreach scientists: Natalie Fischer, Olaf Fischer, Carolin Liefke, Alexander Ludwig, Kai Noeske (since Nov. 2014), Matthias Penselin, Tobias Schultz, Cecilia Scorza, Jakob Staude

Student Assistants: Sophia Haude, Elena Kozlikin, Sebastian Neu, Valentina Rohnacher, Elena Sellentin, Sascha Soh (June and Nov.)

Academic Teaching

Summer Term 2014:

O. Fischer, C. Liefke: Die Erforschung unseres Sonnensystems (seminar), Universität Heidelberg.

C. Liefke: Fernrohrführerschein im Rahmen der Studierendentage (course), Universität Heidelberg.

M. Pössel (with S. Glover): Cosmology Block Course (lecture), Universität Heidelberg.

Winter Term 2014/2015:

N. Fischer: »Astronomie« (physics lecture for future elementary school teachers), Pädagogische Hochschule Heidelberg.

O. Fischer, C. Liefke, C. Scorza, and M. Pössel: Einführung in die Astronomie für Lehramt an Gymnasien Physik (lecture, seminar and practical exercises), Universität Heidelberg.

C. Liefke, O. Fischer: Kosmische Katastrophen (seminar), Universität Heidelberg.

M. Pössel (with B.M. Schäfer): Kosmologie für Nicht-Physiker (lecture), Universität Heidelberg.

Membership in major committees

Carolin Liefke was appointed co-opted board member of the Vereinigung der Sternfreunde (Germany's amateur astronomer association) responsible for schools and outreach to young people

Markus Pössel is the IAU's National Outreach Contact for Germany and a member of the Astronet II Task 5.3 Working Group Implementation of Roadmap recommendations on education, recruitment and training, public outreach, industrial links.

Cecilia Scorza is German coordinator of the "European Association for Astronomy Education", German Coordinator of EUNAWE program, member of the IAU Education Commission, member of the school committee of the Astronomical Society and member of the Office for Astronomy Development (OAD/IAU) as adviser for Latin America.

Jakob Staude was co-editor of "Sterne und Weltraum" (until February 2014) and is now member of the advisory board.

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

Other Activities

Natalie Fischer and Cecilia Scorza supervised two students from Colombia (May-July).

Natalie Fischer developed educational material for Explore Science and for the open day at Max-Planck-Institut für Kernphysik. She also hosted guest scientist Prof. Maria Kallery, Univ. Thessaloniki, during her stay in Heidelberg (November 10.–28).

Carolin Liefke supervised the teacher's masters theses »Der Meteoroid von Tscheljabinsk – Bahnberechnung und Aufarbeitung für die Schule« by Gerrit Fischer. She also supervised the student research project on light-curves of asteroids in cooperation with Hector-Seminar, and she was in charge of three BOGY internships with a total of 18 students (March 10–14, March 17–21, and October 20–24). Liefke supervised German school groups for various campaigns of the International Astronomical Search Collaboration using the Pan-STARRS telescope PS 1 (15, one, and 10 participating schools for the campaigns March 10–14, March 24–April 11, and May 12–28).

Markus Pössel supervised a journalist's internship (March 17–28) and three individual student's internships. He also supervised six participants of this year's "International Summer Internship" (in collaboration with the International Summer Science School of the city of Heidelberg, August 4–22).

7 educator training sessions for kindergarten teachers with a total of 143 participants (N. Fischer)

2 advanced education seminars for kindergarten and elementary school teachers (5 meetings each) in cooperation with Forscherstation Heidelberg, 52 participants (N. Fischer), 5 advisory sessions for educators (N. Fischer)

56 guided tours by HdA staff and 37 Königstuhl guided tours by students of MPIA and LSW with a total of 3413 participants

25 organizational and other meetings (mainly MPIA) with approximately 400 participants

66 workshops for elementary school and kindergarten with a total of 1227 children (N. Fischer, E. Kolar); 27 workshops for families with a total of 322 children (S. Appl, E. Kolar); 35 workshops for grades 5 – 13 with a total of 767 students (N. Fischer, A. Ludwig, M. Penselin, T. Schultz, C. Scorza)

Events

Events held at HdA

Lecture series Faszination Astronomie, 18 lectures, January 9 - December 11, 1611 visitors (organized by C. Liefke)

Spring session of Rat Deutscher Sternwarten (RDS), March 17

Girls' Day (HdA and Max-Planck-Institut für Astronomie), March 27 (C. Liefke und M. Pössel)

Event on the occasion oft he Day of Astronomy, 300 visitors, 5.4. (C. Liefke, M. Pössel)

Heidelberg Joint Astronomical Colloquium, 13 sessions, April 22 - July 22.

Seminar "Data analysis for astronomers," 14 sessions, April 25 - July 25.

Workshop for teachers on using the Faulkes Telescopes, 3.5. (C. Liefke)

D-HST Meeting, May 5–9 (H.W. Rix)

Author's meeting for Wissenschaft in die Schulen! (Astronomy section), May 9–11 (O. Fischer)

Evaluation of the collaborative research center SFB 881 The Milky Way System, May 27–28

Kleinplanetentagung (Minor Planet meeting), June 13–15 (C. Liefke)

Conference Intergalactic Matters, June 16–20 (K.G. Lee)

Space Day at Haus der Astronomie featuring astronaut Reinhold Ewald, July 13 (M. Pössel, C. Liefke)

MPIA Summer Conference 2014 Star Formation: Data, Models and Visualization, June 23–26 (T. Robitaille)

Joint lecture series Astronomie am Sonntagvormittag in cooperation with MPIA, four talks, September 21 - October 12, with a total of 427 visitors (M. Pössel)

Exoplanets with JWST-MIRI, September 22–25 (O. Krause, T. Henning)

Gaia Challenge Meeting, October 27–31 (G. van de Ven)

German-Japanese Meeting on Planet Formation, Detection and Characterization, November 5–7 (H. Klahr)

German-wide Teacher Training in Astronomy, funded by the Wilhelm und Else Heraeus-Stiftung, November 13–15 (O. Fischer)

Two planetarium shows for families (December 7) and three special christmas lectures with a total of 445 visitors (M. Pössel, C. Liefke)

37 smaller scientific meetings with a total of nearly 700 participants

External events

Journey to Chile as part of the DAAD-program promoting astronomy in schools: advanced education units, networking and developing working material for schools in Chile, January 3-February 2 (O. Fischer)

Planetarium presentations at Zeiss' open day, Jena, May 25 (M. Pössel)

Itinerant Teacher Training sessions in Schleswig-Holstein, June 1–8 (O. Fischer, S. Soh)

Hands-on stations for elementary school children (N. Fischer, E. Kolar in cooperation with Astronomieschule e.V.) and for secondary schools at Explore Science (Klaus Tschira Foundation) in Mannheim, July 9–13 (O. Fischer, C. Liefke, A. Ludwig, M. Pössel, T. Schultz, C. Scorza)

Astronomy Workshop, Schülerakademie Rostock: Kleinkörper des Sonnensystems – große und kleine Reste einer Großbaustelle, July 15 - August 3 (O. Fischer)

Children's program at the Max-Planck-Institut für Kernphysik's open day on July 20 (N. Fischer, E. Kolar, M. Pössel)

Journey to La Palma with the science lab at Friedrich-Koenig-Gymnasium Würzburg, July 22–29 (C. Liefke)

Burggespräche St. Albrechtsberg an der Pielach, August 14–17 (C. Liefke)

ScienceAcademy Baden-Württemberg, Adelsheim, May 23–25, August 29-September 11, October 17–19 (C. Liefke)

Organization of a teacher training session at the Jahrestagung der Astronomischen Gesellschaft, September 22–26 (C. Scorza)

Teacher training session at Sternwarte Sonneberg: Kleinkörper des Sonnensystems – große und kleine Reste einer Großbaustelle, September 26 - 30 (O. Fischer)

Teacher training in Bad Wildbad: Kleinkörper des Sonnensystems – große und kleine Reste einer Großbaustelle, October 8 - 10 (O. Fischer, M. Penselin)

Workshop and lecture, Kinderuni Hanau, November 22 (C. Liefke)

Teacher training (Fernrohrführerschein) Adelsheim, November 26–28 (O. Fischer, C. Liefke)

Publications

Fischer, Gerrit: Der Meteoroid von Tscheljabinsk. Bahnberechnung und Aufarbeit ung für die Schule, Staatsexamensarbeit, Universität Heidelberg, June 2014

Fischer, Natalie: »Das Universum in einer Schachtel«, Sterne und Weltraum, 8/2014, S. 91.

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