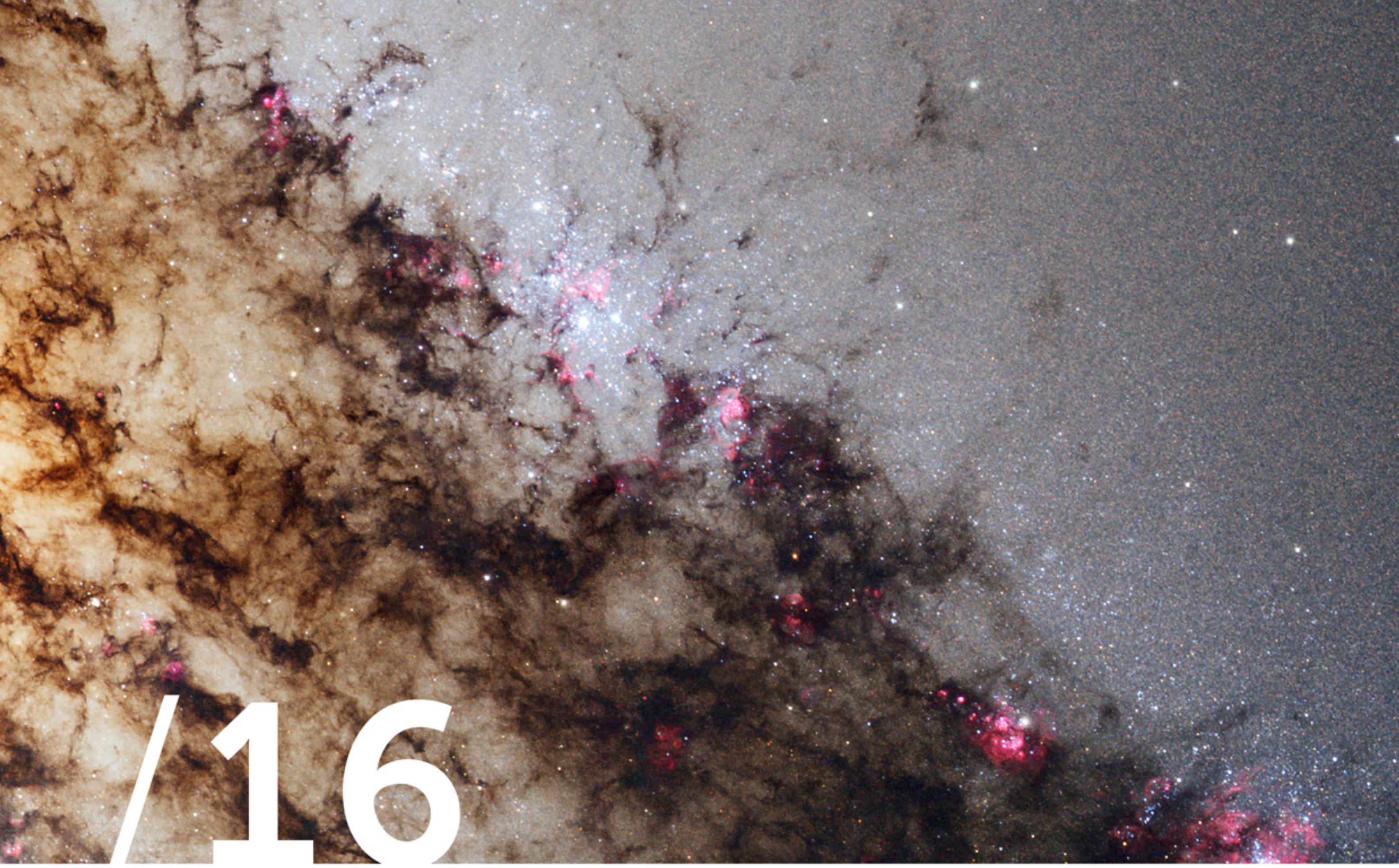

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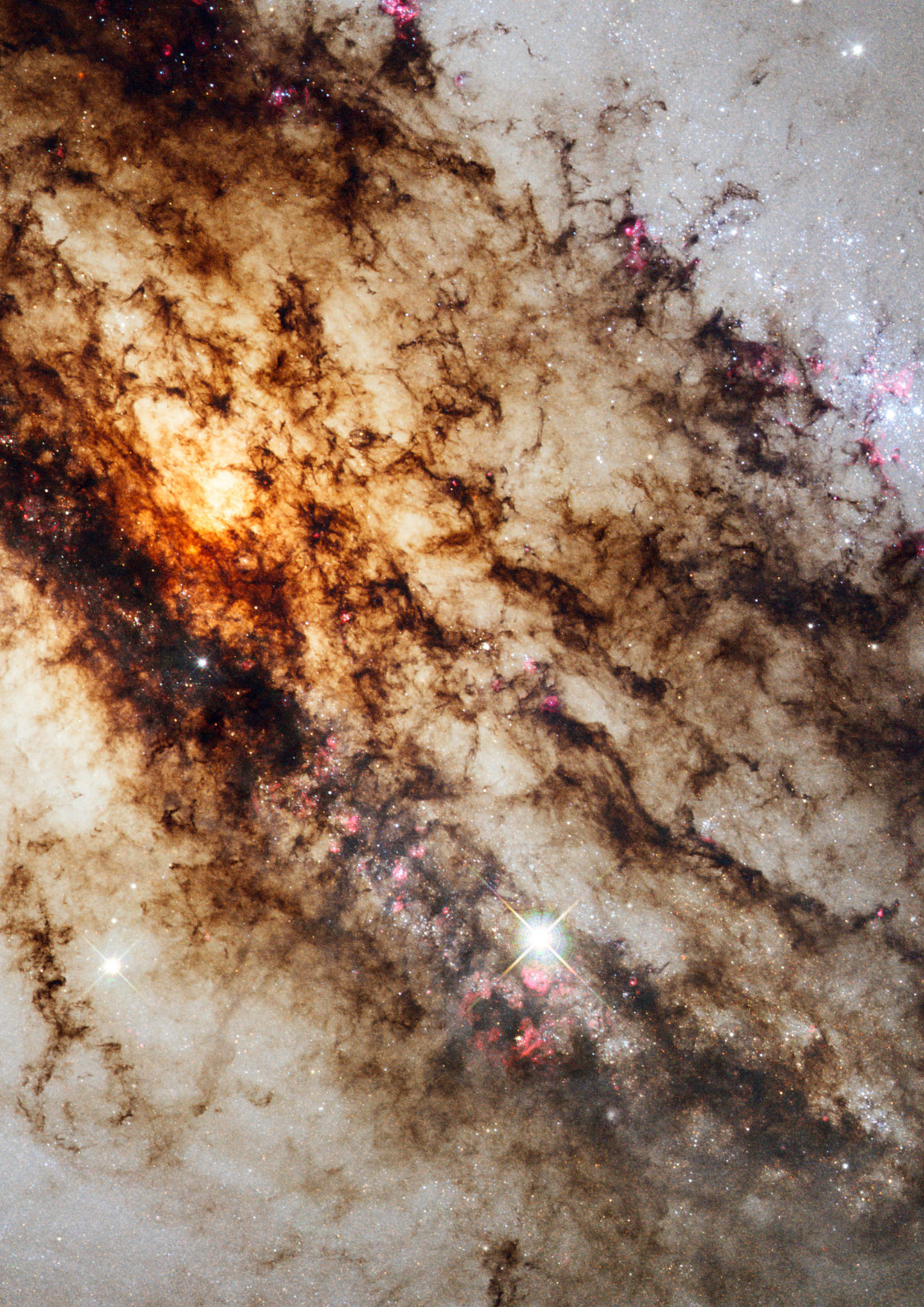
ANNUAL REPORT

Research Institute Leiden Observatory

Onderzoekinstituut Sterrewacht Leiden



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ANNUAL REPORT

Sterrewacht Leiden

Research Institute Leiden Observatory

Onderzoekinstituut Sterrewacht Leiden

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Sterrewacht Leiden

Universiteit Leiden
The Netherlands

Index of **contents**

The Observatory: 2016

Foreword 06

Leiden Observatory 08

Calendar of Events 2016 12

Research Highlights

Koen Kuijken and Henk Hoekstra 17
Observing the dark side of the Universe with gravitational lensing - from KiDS to Euclid

Jacqueline Hodge 20
Tracing the evolution of galaxies with ALMA

Anthony G.A. Brown 23
The Gaia Sky Version 1.0

Harold Linnartz 27
COMETS – Complex Organic Molecules on Extra-Terrestrial Surfaces

Ignas Snellen 29
The search for extraterrestrial life

PhD defences 32

Publication overview 35

Iris Nijman 36
Interview: The academic mothers of Leiden Observatory

Colloquia and Lectures

Scientific colloquia 41

Endowed lectures 43

PhD colloquia 45

Education

Bachelor and Master in Astronomy 47

Academic courses and pre-university Programmes 49

Degrees awarded in 2016 50

Outreach and popularisation

Pre-university program 53

Contact VWO 53

Astronomy & Society Activities 55

Social Networking

L.A.D. “F. Kaiser” 59

VO-S, the Leiden Observatory Alumni Association 60

Organization

Observatory Staff 63

Observatory Committees 67

University Committee Memberships 69

Science policy functions 70

Grants 74

Foreword

Dear **reader**,

In front of you is the annual report of the Leiden Observatory for the year 2016. Thank you so much for all your positive comments on our new-style annual report as introduced last year. We all hope that you like this new report as well.

As last year, we start with a general introduction to the Observatory and its people, and a calendar of the 2016 events. In the research highlights section, you can read about several areas of research for which 2016 was a good year. Koen Kuijken and Henk Hoekstra (NWO VICI winner 2016) present their work on gravitational lensing and Jackie Hodge her work on galaxy evolution with ALMA. Anthony Brown, chair of the data processing and analysis consortium of GAIA, writes about the exciting successes of the GAIA astrometric mission. Harold Linnartz discusses his work on complex molecules in space. Ignas Snellen who was awarded a prestigious Advanced Grant from the European Research Council in 2016, discusses his work on extrasolar planets.

As usual we also highlight other important aspects of activities at Leiden Observatory – education and outreach. At the end, you can find general information about our organization, the names of all Observatory members, their committee memberships and science policy functions.

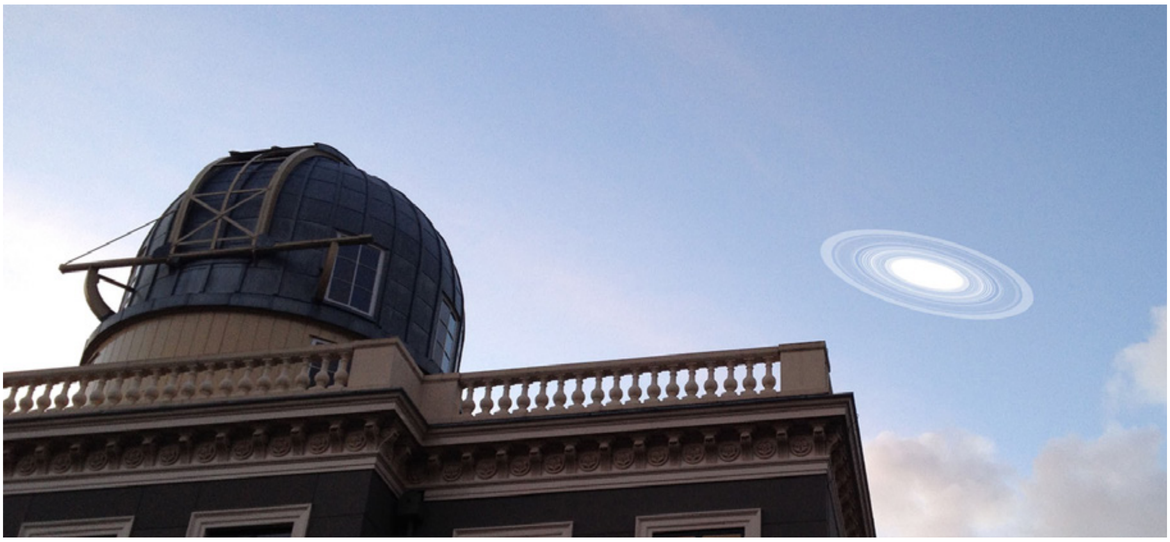
The past year was also very fruitful in a very different way – four Sterrewachters have given birth in 2016. In this annual report, you can find an interview with them that show how they live their scientific life also as a young mother.

Enjoy!

Huub Röttgering, Scientific Director

Leiden **Observatory**

The mission of **Leiden Observatory** is to carry out world-class astronomical research, provide education at bachelors, masters, and PhD level, and inform the general public about the most exciting astronomical results and the beauty of the Universe. Our research is wide-ranging, with a particular emphasis on observational and theoretical studies of galaxies and the structures in which they are embedded, on exoplanets, and on star and planet formation.



The **Observatory** and its **people**

Sterrewacht Leiden was founded by the Leiden University in 1633 to house the quadrant of Snellius, making it the oldest operating university observatory in the world. While originally located at the main Faculty Building of the university, a purpose-built observatory was constructed in the university's botanical gardens in 1860. Since the mid-1970s the institute has been located within the campus of the Faculty of Science. A long list of eminent astronomers has populated the Sterrewacht, including Profs. Willem de Sitter, Ejnar Hertzsprung, Jan Oort, Adriaan Blaauw, and Henk van de Hulst. Currently, Leiden Observatory is proud to be one of the largest and top astronomical research institutes in Europe. It has 25 scientific staff members, about 80 postdoctoral researchers, 90 PhD students, and 250 undergraduates. Among its professors are three Dutch Spinoza Prize winners. Prof. Tim de Zeeuw was the Director General of the European Southern Observatory – the largest observatory in the world, and Prof. Ewine van Dishoeck is the president elect of the International Astronomical Union (2018-2021).

Research & Technology

Leiden Observatory is part of the Netherlands Research School for Astronomy (NOVA). Scientific research at Leiden Observatory ranges from studying how the Earth and the Solar System have formed and how this compares to other planetary systems, to the origin and evolution of the Milky Way and the Universe as a whole. Observations play a central role in astronomical research, and the state-of-the-art instrumentation is almost exclusively built and operated through international collaborations. Optical and infrared ground-based observations are mostly conducted with telescopes from the European Southern Observatory (ESO) in Northern Chile, and from the Isaac Newton Group (ING) on La Palma (Canary Islands, Spain). Flagship telescopes at other wavelength regimes are the Atacama Large mm/sub-mm Array (ALMA) in Chile and the international Low Frequency Array (LOFAR), which has its core in the north of the Netherlands. Other observations can only be conducted from space, meaning that Leiden astronomers also frequently use the NASA Hubble Space Telescope. A second pillar of astronomical research is theoretical and astrochemistry modeling. Large-scale numerical simulations and big data are key ingredients of astronomical research. Leiden Observatory hosts the Sackler Laboratory for Astrophysics, that carries out unique experiments to simulate inter- and circumstellar conditions in a controlled environment.

Leiden Observatory is also focused on driving the development of key-technologies that will enable future astronomical discoveries. Close collaborations with Dutch partners are crucial, such as the NOVA optical group at ASTRON, TNO Delft, the Netherlands Institute for Space Research (SRON), and Dutch Space. Ultimately, most instruments are built in international consortia under the umbrella of ESO or the European Space Agency (ESA). In this way, Leiden astronomers play important roles in the development and operation the ESA's GAIA and EUCLID missions. Leiden professor Bernhard Brandl is for NOVA principal investigator of METIS, one of the first-light instruments of the future European Extremely Large Telescope (E-ELT).

Bachelor & **Master** education

Leiden Observatory is part of the Faculty of Science and hosts both the Bachelor and Master studies in astronomy of Leiden University. The three-year bachelor in astronomy is currently followed by about 200 students, and provides a broad basis in astronomy, with important components in physics, mathematics, and informatics. The two-year master in astronomy is currently followed by about 50 students. Since it is fully taught in English it is also very popular among non-Dutch students. The master will prepare students for a scientific path, but is also often useful to launch a career in business or industry.

In collaboration with ESTEC in Noordwijk, Leiden Observatory organises every year the Leiden/ESA Astrophysics Program for Summer Students (LEAPS), in which talented students from all over the world conduct a summer research program at the Observatory.

Public **Engagement**

An important task of Leiden Observatory is to engage the general public with the wonders of the universe, and share the scientific, technological, cultural, and educational aspects of astronomy with society. It operates a modern visitor centre at the historic observatory building in the centre of town, where the astronomy student club L.A.D.F. Kaiser conducts about two-hundred guided tours a year of the antique telescopes.

Leiden Observatory also hosts the international office of the Universe Awareness programme, UNAWE, which uses the excitement of astronomy to interest young children in science and technology and to use the perspective and enormity of the Universe to foster tolerance and a sense of world citizenship at an age when their value systems are forming. UNAWE is active in 60 countries with teacher training and production of educational materials.

Calendar of
Events 2016

January

- **[5]** Nienke van der Marcel wins the C.J. Kok award for Dissertation of the year 2015.
- **[5]** The VANDAM Survey a team of scientists, including John Tobin, gives new insight into the formation of multiple-star systems.
- **[13]** LAPP-TOP Astronomy starts this year with 29 students.
- **[14]** Simon Portegies Zwart publishes a model that explains how clusters obtain their structure, and why some stars have larger debris disks compared to others.

February

- **[10]** Koen Kuijken is awarded a NWO Large Investment Grant.
- **[12]** Henk Hoekstra is awarded a NWO Vici grant.

March

- **[3]** Simon Portegies Zwart is awarded a NWO Medium Investment Grant.
- **[3]** An international team of astronomers, including Marijn Franx, Ivo Labbé, and Rychard Bouwens, discover a galaxy at a record distance - at a redshift of 11.1.
- **[17]** Two bachelor students, Isabel van Vledder and Dieuwertje van der Vlugt, map for the first time the Milky Way galaxy in dwarf stars using the Hubble Space Telescope.
- **[18]** The Lustrum Symposium ‘Science Matters’ is held to celebrate the 200th anniversary of the Faculty of Science.
- **[30]** The prestigious Edinburgh Medal is awarded to Astronomy for Development, the brainchild of George Miley.
- **[31]** Ignas Snellen is awarded an ERC Advanced Grant.

April

- **[2]** The Kaiser Spring Lectures start in the historic Observatory building.
- **[22]** The Oort Lecture is given by Professor Joe Silk on ‘Limits of the Cosmos’.
- **[24]** Premiere of the documentary ‘Are we Alone’ by Charlotte Lemmens and Vincent Icke.

May

- **[9]** Mercury’s transit of the Sun, an event that was followed by the Leiden Observatory’s new solar telescope.
- **[13]** Jacqueline Hodge is awarded a NWO Vidi grant.

June

- **[3]** Academy Prize Astronomy & Art, offered by Ewine van Dishoeck, is awarded to Roland Schimmel.
- **[9]** ALMA delivers sharpest view ever of star formation in the distant universe.
- **[10]** Ewine van Dishoeck received the Einstein World Award of Science
- **[12]** Simulations by Lucie Jilkova and Simon Portegies Zwart indicate that Kuiper-belt object Sedna orginates from a different star than the Sun.
- **[17]** VLT gives best proof yet of first generation of stars in the distant universe, as shown by a research team including David Sobral, Jorryt Matthee, and Huub Röttgering.
- **[22]** Vector Apodizing Phase Plate (vAPP) is installed on the 6.5m Magellan Clay-Telescope, proving a world-class contrast to search for exoplanets.

Symposium in the honour of the 80iest birthday of Prof. Harry van der Laan.

July

- **[8]** Universe Awareness (UNAWE) celebrates its 10th anniversary.
- **[13]** Renske Smit wins an NWO Rubicon grant.
- **[14]** Researchers, including John Tobin and Steven Bos, produce the first images of the water snow line within a protoplanetary disk using ALMA.
- **[15]** Alvaro Hacar is awarded a Veni grant.

August

- **[6]** Leiden Observatory hosts the first HaloHalo event in Leiden, bringing together recently arrived refugees and local citizens.
- **[31]** An international team of researchers, including Pascale Ehrenfreund, confirms that clumps of dust form the basis of comets and planets, based on atomic force microscope analysis of the comet 67P/Churyumov-Gerasimenko by the Rosetta spacecraft.

September

- **[1]** UNAWE starts a month-long educational programme at Basisschool De Verrekijker, a primary school for refugee children in Katwijk.
- **[5]** Space Awareness launches their first Massive Open Online Course (MOOC).
- **[9]** Several international teams of astronomers, including Richard Bouwens and Paul van der Werf, have observed the Hubble Ultra-Deep Field with ALMA – the sharpest and deepest image ever at these wavelengths.
- **[12]** Leiden Observatory Science Day.
- **[26]** Bernhard Brandl delivers his inaugural lecture, as the new Leiden Professor of Infrared Astronomy.

October

- **[13]** Steven Rieder and Matthew Kenworthy determine that the gigantic ring system around the planet orbiting the star J1407 can be stable over a long period if the rings orbit in the opposite direction to the planets orbit around the star.
- **[18]** Leiden hosts the International Space Education Workshop.
- **[30]** Open Day at the historic Leiden Observatory building.
- **[31]** KNAW presents 13 desirable future research facilities, including LISA, LOFAR2.0, and EPICS at the E-ELT.

November

- **[2]** Rychard Bouwens wins a NWO TOP grant.
- **[9]** Three teams, including one led by Jos de Boer and another led by Christian Ginski, show that protoplanetary disks are shaped by newborn planets using SPHERE observations.
- **[16]** An international team of astronomers, including Maciej Bilicki, discover an enormous supercluster, the Vela supercluster, using the Anglo-Australian Telescope.
- **[24]** The 18th Raymond and Beverly Sackler Lecture is given by Prof. Sarah Bridle.
- **[29]** UNAWE and Design & Data GmbH starts a crowdfunding campaign where donors could either buy a Rosetta plush or donate one to underprivileged schools.

December

- **[2]** An international team of researchers, including George Miley and Huub Röttgering, discover that large galaxies, such as the Spiderweb galaxy, grow by 'consuming' an enormous, cold, gas cloud.
- **[5]** Sterrewacht Sinterklaas Event.
- **[9]** An international team of astronomers, led by Massimo Viola, discover that dark matter may be less dense and more smoothly distributed than previously believed.
- **[12]** Frans Snik is invited to The Young Academy
- **[12]** A team of researchers led by Margot Brouwer have tested for the first time Verlinde's theory of emergent gravity by means of gravitational lensing.
- **[23]** Sterrewacht Christmas Lunch.

Bachelor degree ceremony.

Research Highlights

Observing the **dark side** of the Universe with **gravitational lensing** - from **KiDS** to **Euclid**

Koen Kuijken and Henk Hoekstra

The past three decades have seen tremendous advances in cosmology. A powerful interplay of observations, theory and massive computer simulations now allow us to describe the Universe and the evolution of its large-scale structure with a single cosmological model, dubbed ΛCDM. The model successfully reproduces key observations such as the anisotropies in the cosmic background radiation, primordial element abundances, supernova distances, and large-scale clustering of matter.

This success comes at a price though: the present-day ΛCDM Universe consists of 26% dark matter, 69% dark energy, and only 5% in the form of 'baryonic' matter of the kind that is known to particle physics. The nature of dark matter and dark energy is not understood, but without these ingredients the expansion history of the Universe, and the clustering of matter, cannot be fitted. Dark matter is furthermore evident in the masses of galaxies and galaxy clusters.

It is clear that the model is sufficiently strange that it warrants stringent testing. Gravitational lensing by large-scale structure, a.k.a. cosmic shear, is one of the most direct probes that we can use. Gravitational lensing measures the bending of light rays by gravity, and as such probes all matter, whether dark or baryonic. In essence, observations of distant galaxies are affected by small distortions that, if measured accurately, reveal the intervening mass distribution along the line of sight.

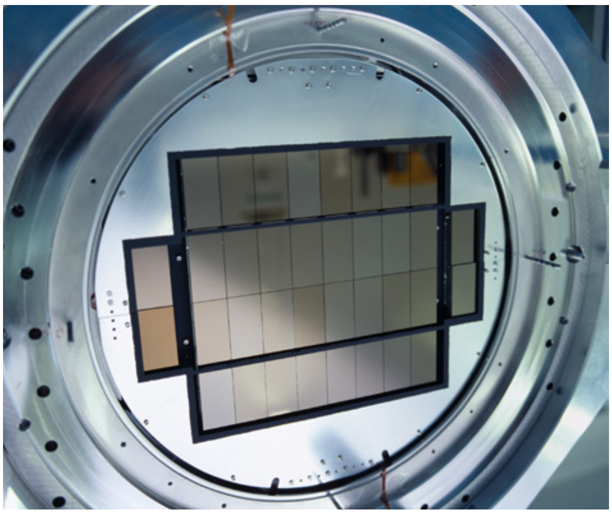


Fig.1: The 300-megapixel OmegaCAM camera for the VLT Survey Telescope, which was used to make the KiDS measurements.

Studying the dark Universe through gravitational lensing is the main aim of the Kilo-Degree Survey (KiDS), a large project underway at the VLT Survey Telescope (VST) at ESO's Paranal observatory in Chile. KiDS started taking data late in 2011, using a purpose-built wide-field CCD mosaic camera developed as part of NOVA's instrumentation programme, in collaboration with ESO and institutes in Germany and Italy. The VST delivers excellent image quality, which is essential to be able to measure the subtle, weak distortions due to gravitational lensing accurately.

In fact, KiDS data enable a tomographic analysis of the large-scale structure: from measurements of the lensing effect to galaxies at a range of different distances, the 3D structure of the mass distribution can be (statistically) deduced. Because distance is tied to look-back time, this means that surveys like KiDS can directly trace the growth of large-scale structure with cosmic time!

In 2016 the first such analysis, based on 450 square degrees of KiDS data, was completed. Comparing the measurements to cosmological models showed good agreement with expectations, although the degree of clustering of matter appears a little lower than what the best CMB-based models predict. As the survey continues, and new data are analysed, we will be able to investigate the significance of this discrepancy further, and assess whether it was a statistical fluke, or whether it firms up into a clear hint at the need for modifying the cosmological model. The most exciting possibility is that the discrepancy indicates the need for new physics, such as a more complicated dark energy model, decaying dark matter, or even a radically different theory of gravity. Right now it is too early to tell, but these are the types of measurements that will allow us to decide.

To learn more about the nature of dark energy and the other puzzling aspects of the ΛCDM paradigm, we need to measure shapes of much larger numbers than the nearly 50 million galaxies that KiDS will observe. However, the increase in precision needs to be matched by a similar improvement in the control for various observational sources of bias, that can otherwise overwhelm the subtle cosmological signal. The most important effect is the blurring of images caused by turbulence in the atmosphere; this ultimately limits our ability to model the impact it has on the measurements of the shapes of galaxies. Only space can provide the stable environment to provide us with the sharp and stable images we need to scrutinize the current cosmological model. This is why the European Space Agency has selected Euclid as its next cosmology mission to "explore the dark Universe" for a scheduled launch in 2020. The scientific impact of Euclid, however, spans most of extra-galactic astro¬nomy: the unique combination of high-resolution optical imaging, multi-band near-infrared imaging and spectro¬scopy up to z~2 over half of the extra-galactic sky, will result in a vast legacy of non-cosmology science.

Euclid is designed to measure the lensing signal by imaging 1.5 billion galaxies with a resolution similar to that of the Hubble Space Telescope. These observations will be complemented by observations at near-infrared wavelengths to improve distance estimates for these galaxies, which are needed for the tomographic analysis. Euclid will also measure emission-line redshifts for a large number of galaxies beyond the reach of ground-based observatories. The analysis of such a large data set requires custom-made pipelines, and the complexity of the measurements relies on exquisite quality control. In 2016 a team led by Kuijken secured NWO funding to support the Dutch contribution to the software development. The work in Leiden focuses on improvements in the algorithms used to measure shapes and the processing of the near-infrared images.

To correctly interpret the Euclid data it is paramount that we can model the astrophysical effects that contaminate the signal. For instance, galaxies can also intrinsically align with each other due to the gravitational tidal forces exerted by the surrounding large-scale structure. These intrinsic alignments thus provide a unique probe of the role of large-scale structure in galaxy formation and evolution, but they also hamper a simple interpretation of the lensing data. To directly constrain models of intrinsic alignments, Hoekstra and Kuijken, together with colleagues in Spain and the UK started a unique survey with the William Herschel Telescope: thanks to 40 narrow-band filters and a new camera, the PAUCam Survey can determine photometric redshifts with a precision that approaches that of spectroscopic surveys. This research, funded by a Vici grant awarded to Hoekstra, also improves observational constraints on energetic processes that affect the distribution of hot gas in groups and clusters of galaxies.

Many details still need to be solved in the coming years before we can fully exploit the statistical power of the Euclid data to study the nature of dark energy and to address many other open questions in cosmology. The lessons learned from the analysis of ongoing surveys are instrumental to achieve this.

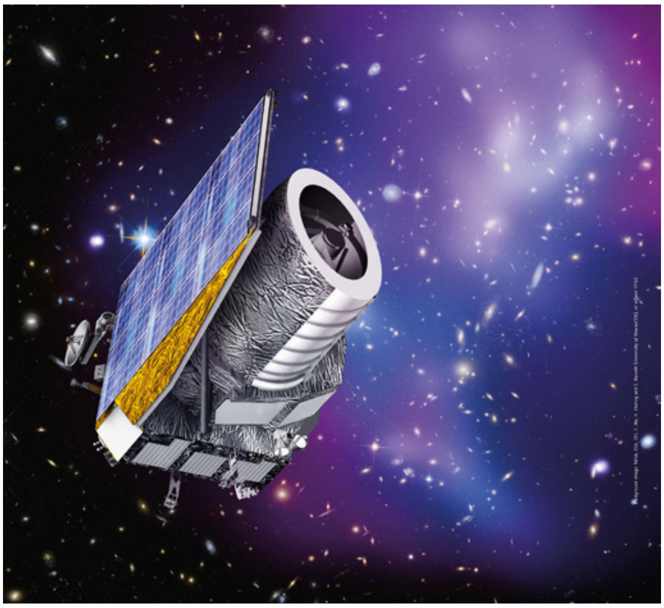


Fig.2: Artists's impression of the Euclid satellite, ESA's cosmology mission to be launched in te early 2020's.

Fig.3: VLT Survey Telescope (VST) at ESO's Paranal observatory in Chile

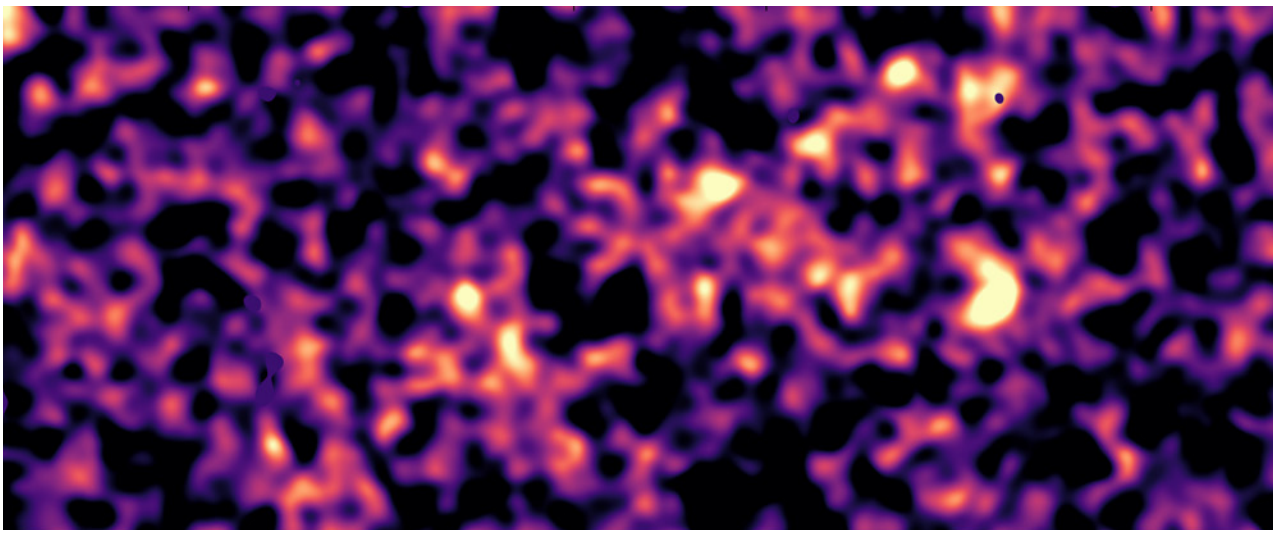


Fig.4: A section of the reconstructed dark matter map, derived from KiDS weak gravitational lensing measurements.

Tracing the **evolution** of **galaxies** with **ALMA**

Jacqueline Hodge

Cosmic dust is everywhere in the universe: it is present in the Earth's own atmosphere, it pervades the space between the planets in our solar system, and it is plentiful in the distant galaxies that are currently forming their stars. In astronomy, it has historically been viewed as a nuisance – obscuring the starlight from newly formed stars, and thus rendering actively star-forming galaxies faint or invisible at short wavelengths. This has presented a huge challenge for studies of galaxy evolution, which ultimately strive to determine when and how galaxies formed their stars.

Despite this challenge, the last twenty years have witnessed huge progress in efforts to piece together the assembly history of galaxies. By relying heavily on observations of the unobscured starlight, we now know that galaxies formed most of their stars between redshifts of z~1-3, when the Universe was only a fraction of its present age. And indeed, during this peak epoch of galaxy assembly, the vast majority of that star formation was shrouded in dust. This dust makes tackling the second part of the question – the 'how' – very hard. In particular, it is still not understood how galaxies built up their bulges and stellar disks, nor for which populations violent collisions played a significant role. The most massive star-forming galaxies should (in principle) be the easiest to study – they have the highest intrinsic luminosities, as they are forming the largest quantity of stars. The most prolific examples – originally discovered through their submillimeter wavelength emission -- are forming stars at 100s to 1000s of solar masses per year – orders of magnitude higher than our own Milky Way. Unfortunately, in addition to their abundant star formation, these galaxies also have vast quantities of cosmic dust.

The era of ALMA

What is required to make progress toward a complete picture of galaxy assembly are submillimeter telescopes that can view the dust-obscured star formation in these distant galaxies directly. The technical challenge this presents meant that previous-generation submillimeter telescopes had extremely poor angular resolution – so poor that multiple galaxies could be blended together into one. Far from resolving the hidden star formation in early galaxies, this meant that high-redshift studies had to first tackle the more basic issue of identifying which galaxies were responsible for that star formation in the first place.

This is now changing thanks to the advent of the Atacama Large Millimeter Array (ALMA). With its ability to detect dust-reprocessed starlight, ALMA will reveal dusty galaxies which were previously invisible. Through the negative k-correction (i.e., that the submillimeter flux is approximately constant for redshifts greater than one), these galaxies will be detectable out to extreme lookback times (within <1 billion years of the big bang). Finally, and most critically, the combination of ALMA's unprecedented sensitivity with its long baselines will probe star formation and molecular gas with a resolution comparable, for the first time, to optical studies. With these abilities, ALMA will usher in a new era where dust goes from being a bother to a benefit, and the era of ALMA has arrived.

Galaxies under construction

Early work with some of ALMA's first science-quality data already allowed researchers to identify the distant, dusty galaxies responsible for the majority of the dusty star formation in one of the prime extragalactic deep field: The Extended Chandra Deep Field South. This study demonstrated that a significant fraction of the submillimeter-detected sources were actually blends of multiple galaxies, and the precise identification of those galaxies allowed their basic physical properties to be reliably studied for the first time (Figure 1). However, in that early study, each of the now precisely-located galaxies was still unresolved.

Now, in a recent study led by researchers at Leiden Observatory, ALMA has resolved the star formation within these dusty galaxies, allowing a first dramatic look at their nature on sub-galactic (kiloparsec) scales (Figure 2). These data reveal compact (≤ a few kiloparsecs) dust disks nestled within the more extended and chaotic unobscured stellar distributions, suggesting that major mergers may be responsible for driving the formation of the compact dust disks. The extreme morphological contrast also indicates that the current bursts of dusty star formation have the potential to transform both the observed galaxy sizes and overall light profiles. This observation could help establish the link between these luminous star-forming galaxies observed during the peak epoch of star formation and the red-and-dead elliptical galaxies observed locally.

Molecular gas: The fuel of the stars

While the dusty star formation revealed by ALMA already provides valuable clues on the nature of the luminous high-redshift galaxy population, a more fundamental observable is the molecular gas that is fueling that star formation in the first place. Molecular gas observations reveal not only the reservoirs of raw material available for star formation, but also how efficiently the galaxies are turning that raw material into stars. Unfortunately, much like the earlier generation of submillimeter continuum observations, most previous molecular gas observations of distant galaxies were low-resolution and thus unresolved.

Here, ALMA is once again proving its worth. In a new ALMA program led by Leiden Observatory researchers, the cold molecular gas in a distant dusty star-forming galaxy is resolved on similar sub-galactic scales as the stars. Interestingly, the cold gas appears significantly more extended than the current burst of star formation. This observation provides some of the first evidence for a higher efficiency of star formation in the cores of these distant massive galaxies, and it places valuable constraints on the so-called 'star formation law'.

Despite not yet being complete, ALMA has already been hugely successful, and it will become even more powerful as its capabilities continue to grow. The complete array will be even more sensitive, with wider frequency coverage and higher resolution to resolve even finer detail. For galaxy evolution studies, this means the ability to do dynamical studies of the gas motion within distant galaxies, as well as to resolve individual star-forming regions analogous to local giant molecular clouds. Different molecules will shed light on the state of the ISM at different redshifts as well as help identify and characterize the very first galaxies. Ultimately, and in combination with multi-wavelength information, systematic studies with ALMA of galaxies across the luminosity function will help shed new light on the dusty history of galaxy assembly as a whole.

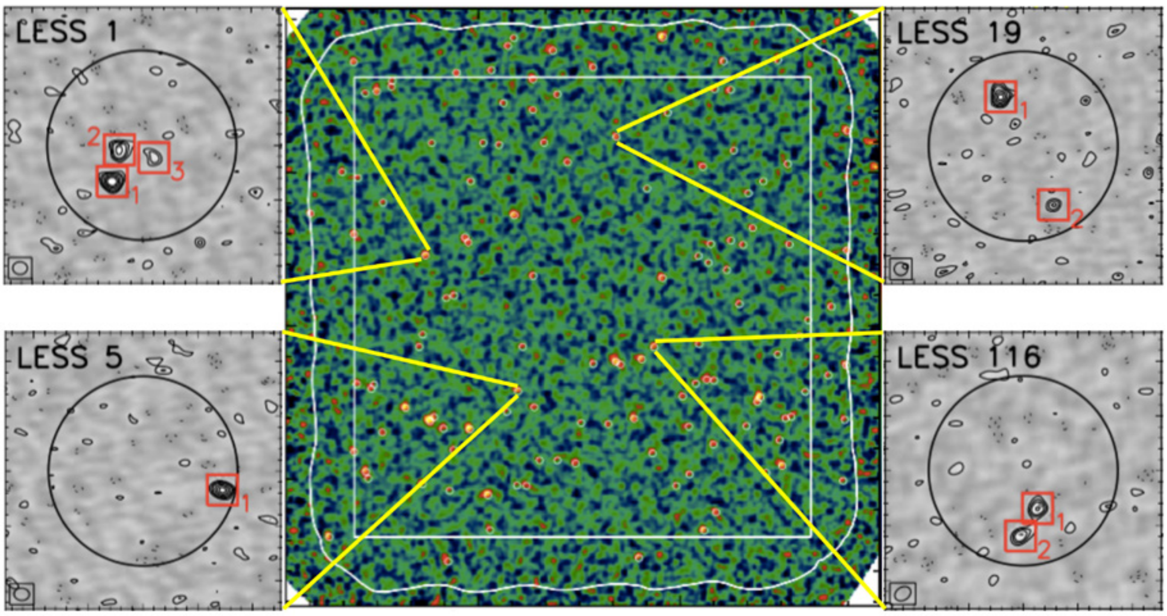


Fig.1: Early work with ALMA precisely located the distant dusty star-forming galaxies in the 30'x30' Extended Chandra Deep Field South for the first time. However, each of the precisely located galaxies was still unresolved. (Figure adapted from Weiss et al. 2009 and Hodge et al. 2013.)

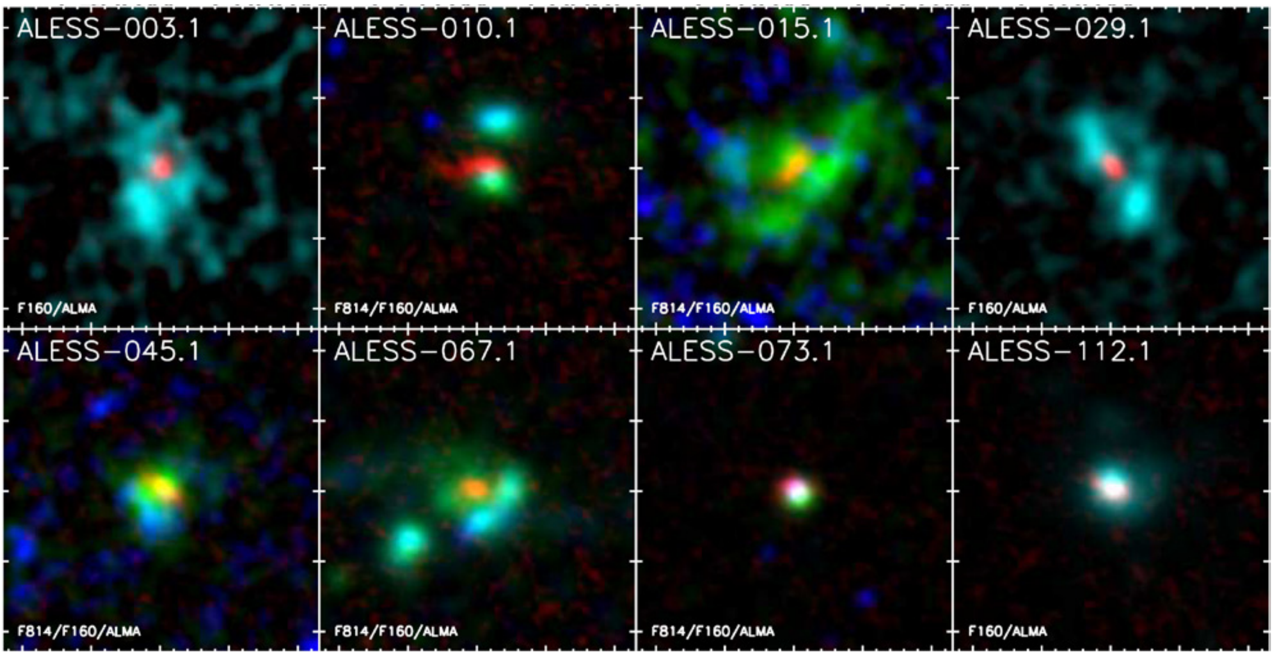


Fig.2: Recent ALMA work (Hodge et al. 2016) provides a first dramatic look at the morphology of the dusty star formation within these highly star-forming distant galaxies. These false-color images showing the ALMA (red) and HST I814/H160-band data (green/blue) reveal compact dust disks nestled within the more extended and chaotic unobscured stellar distributions, suggesting that major mergers may be responsible for driving the formation of the compact dust disks.

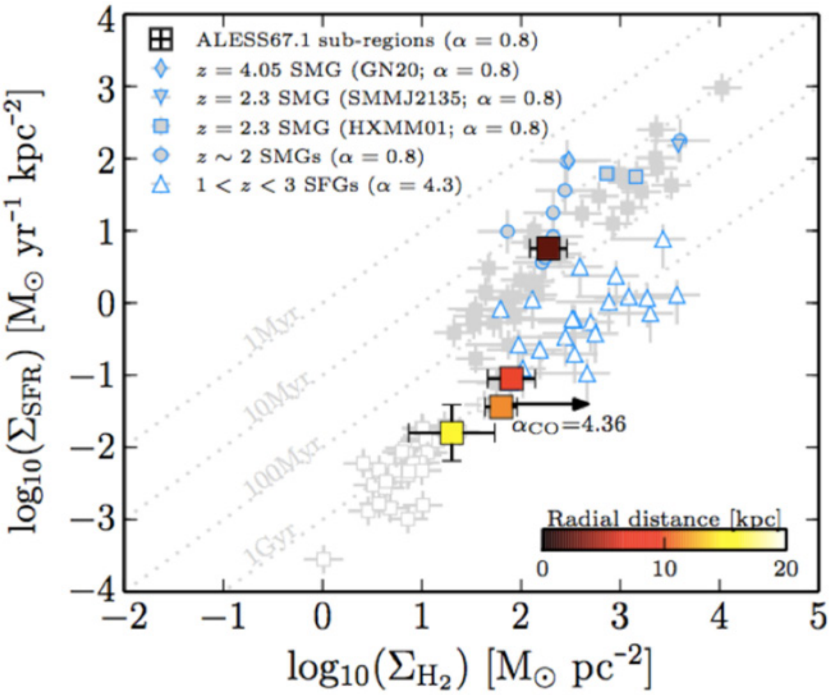


Fig.3: The latest ALMA observations resolve the cold molecular gas within a distant star-forming galaxy on similar scales as the stars, providing some of the first evidence for a higher efficiency of star formation in the cores of these distant massive galaxies. (Figure adapted from Chen, Hodge et al. 2017.)

The **Gaia Sky** Version **1.0**

Anthony G.A. Brown

The astronomical community entered the so-called Gaia era with the announcement on September 14 2016 of the first data release from the ESA Gaia mission (Gaia DR1). This data release was the culmination of over 10 years of effort by ESA and the members of the Gaia Data Processing and Analysis Consortium (DPAC), the community of European astronomers responsible for the data processing for the Gaia mission. Leiden and NOVA astronomers are involved in the photometric data processing, the validation of the data produced by DPAC, and the development of algorithms to detect transients with Gaia. The author is currently the chair of the DPAC Executive.

The Gaia satellite was launched in December 2013 to collect data that will allow the determination of highly accurate positions, parallaxes, and proper motions for over one billion sources brighter than magnitude $G = 20.7$ in Gaia's white-light photometric band. The astrometry is complemented by multi-colour photometry, measured for all sources observed by Gaia, and radial velocities which are collected for stars brighter than $G \approx 17$. The scientific goals of the mission and the scientific instruments onboard Gaia are summarised in Gaia Collaboration et al. (2016a). The raw data collected during the first 14 months of the mission were processed by the DPAC, involving some 450 astronomers and IT specialists, and turned into the first version of the Gaia catalogue of the sky.

The bulk of Gaia DR1 consists of celestial positions (α,δ) and G-band magnitudes for about 1.1 billion sources. With median positional accuracies of 2.3 milli-arcsec (mas) and a spatial resolution comparable to the Hubble Space Telescope, this represents the most accurate map of the sky to date, including the most precise and homogeneous all-sky photometry, ranging from milli-magnitude uncertainty at the bright end of the Gaia survey to 0.03 magnitude uncertainty at the faint end. In addition, the combination of Gaia data and the positions from the Hipparcos and Tycho-2 catalogues allowed the derivation of highly precise proper motions and parallaxes for the 2 million brightest sources in Gaia DR1 (the so-called Tycho-Gaia Astrometric Solution or TGAS). The typical parallax uncertainty is ~ 0.3mas, while the proper motions are accurate to about 1 mas yr^{-1} for the stars from the Tycho-2 catalogue and as precise as 0.06 mas yr^{-1} for the stars from the Hipparcos catalogue. Gaia DR1 in addition contains light curves and variable type classifications for a modest sample of some 2600 RR Lyrae and 600 Cepheid variables as well as the optical positions of about 2000 ICRF2 sources. More details can be found in Gaia Collaboration et al. (2016b).

The quality of the Gaia DR1 data as well as the enormous advance the catalogue represents over previous parallax and proper motion surveys is illustrated through the Hertzsprung-Russell diagrams shown in figures 1 and 2. Figure 1 shows the observational HR diagram for just over 1 million (!) stars for which the parallaxes are known to better than 20 per cent uncertainty and for which 2MASS photometry is available. For this sample 90 per cent of the stars are within about 590 pc, thus covering a substantially larger volume than Hipparcos reached at the same uncertainty level. The larger volume covered is also evident from the large number (>190000) of luminous stars at $M_G < 2$ and from the visible effect of extinction on the prominent red clump and sub-giant sequences. Figure 2 illustrates the power of accurate astrometry through a version of the HR diagram (see Gould, 2004) which is colour coded according to the transverse velocity of the stars $\upsilon_\perp = \mu/\varpi \times 4.74$ (in km s^{-1}), where μ is the length of the proper motion vector of the star, and ϖ the parallax. The stars in this diagram are all bright ($G<7.5$), selected from the Hipparcos, Tycho-2, or APASS catalogues (all listing a ($B-V$) colour), and have parallax uncertainties smaller than 20 per cent. The proper motions are larger than 200 mas yr^{-1} and the parallaxes are larger than 10 mas. The resulting collection of about 41000 stars beautifully illustrates the well-known mix of stellar populations contained in a sample around the Sun. At low velocities the young disk stars along the main sequence are outlined ($\upsilon_\perp < 50$km s^{-1}). The turn-off region for the old disk is visible at 50km $s^{-1} \leq \upsilon_{\perp} \leq 100$km s^{-1}, while at higher velocities halo stars are visible, which along the main sequence are clearly shifted to the lower metallicity region.

The success of Gaia DR1 can be measured by the fact the on average one paper based on Gaia DR1 appeared every two working days after the release date. The first such paper appeared on arxiv.org within half a day of the announcement of Gaia DR1 and it discusses the kinematics of the Large Magellanic Cloud as measured by Gaia (van der Marel & Sahlmann, 2016). Figure 3 shows the residual proper motions with respect to mean for the small sample of stars in TGAS which are located in the LMC. The residuals of the proper motions show a very clear rotation pattern. The rotation pattern was already seen in HST studies and leads to a rotation curve which is consistent with the result from line-of-sight motions. This is just a preview of what can be done with Gaia proper motions once the latter are measured for the millions of stars in the LMC.

Finally, the power of an all-sky deep parallax survey is illustrated by the work of E. Zari (Leiden) on the Orion OB association and its wider surroundings. Figure 4 shows the distribution of TGAS sources in the area of the sky around the Orion constellation for various parallax slices. At the smallest parallaxes the stars, located far from the Sun, are partially obscured by the Orion A and B molecular clouds which are nicely outlined in the top left panel of the figure. The lower left panel reveals a concentrated population of stars at parallaxes around 3 mas. Further study of the full set of Gaia DR1 sources in this region (i.e., including those without parallax information) reveals that this set of stars corresponds to an extended population of young stars in the Orion region which has not been mapped to this extent before. Future Gaia data releases will allow the full 3D spatial and kinematic mapping of the stellar populations in Orion, allowing accurate studies of the relation between the astrophysical characteristics of the young Orion populations and the structures in the surrounding ISM.

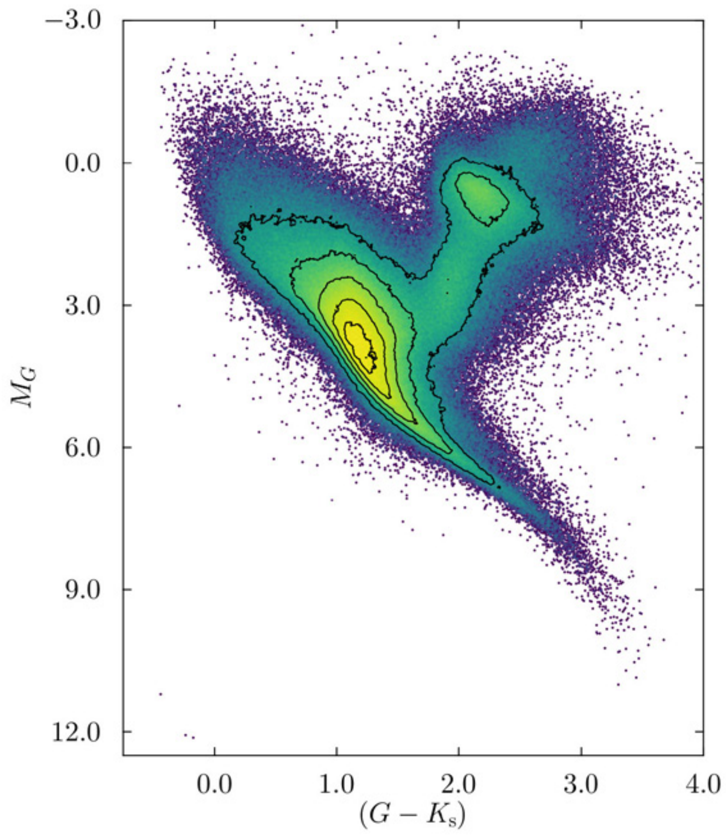
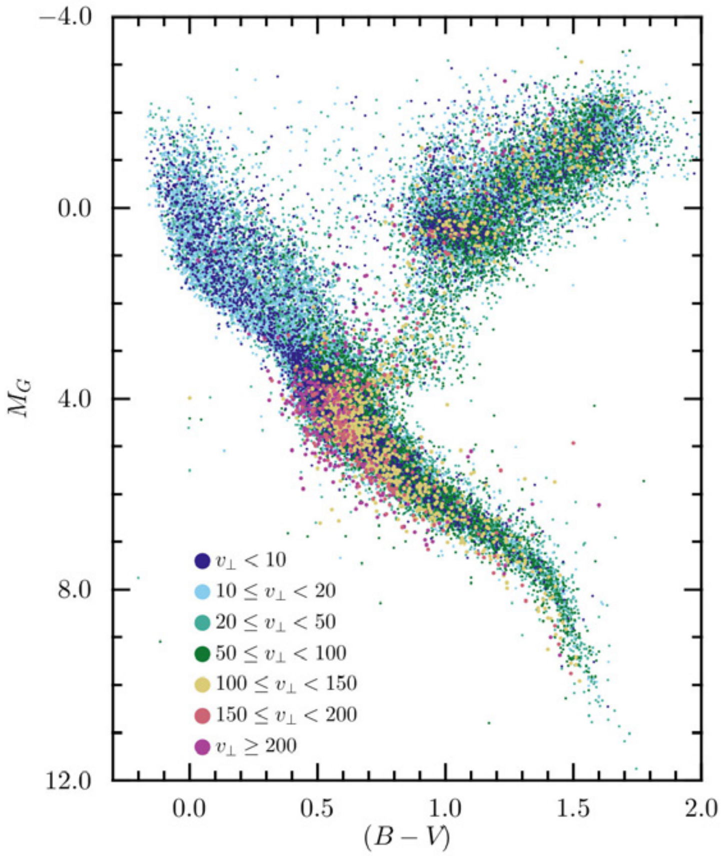


Fig. 1: Observational HR diagram for all stars in Gaia DR1 with relative parallax uncertainties less than 20% and for which the (G–K_s) colour index can be calculated from Gaia DR1 and the data in the 2MASS Point Source Catalogue. The stars are shown as individual symbols where possible and where the symbols overlap the relative source density is shown, with colours varying from purple (dark) to yellow (light) indicating increasing density on a logarithmic scale. The contours enclose 10%, 30%, 50%, 70%, and 90% of the data. Figure from Gaia Collaboration et al. (2016b).

Fig. 2: Observational HR diagram constructed from Gaia DR1 and photometric surveys listing (*B*–*V*), showing where stars with specific values of the transverse velocity $v_\perp$ tend to occur. The colour coding of the points is according to tangential velo interval, as indicated in the legend (in km s^{-1}). Figu from Gaia Collaboration et al. (2016b).



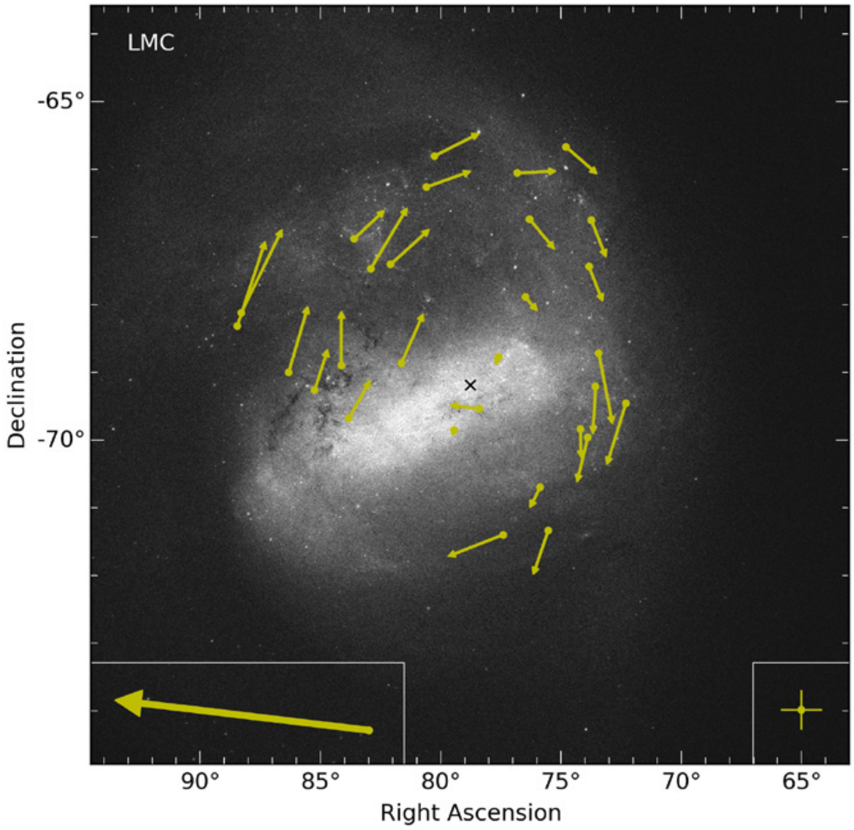


Fig. 3: Residual proper motions of Hipparcos stars in the LMC, as measured by Gaia. The residuals are with respect to the mean proper motion of the LMC and reveal a beautiful rotation pattern. The source distribution in the background is from the Gaia DR1 sky map. Credits: Johannes Sahlmann and van der Marel & Sahlmann (2016).

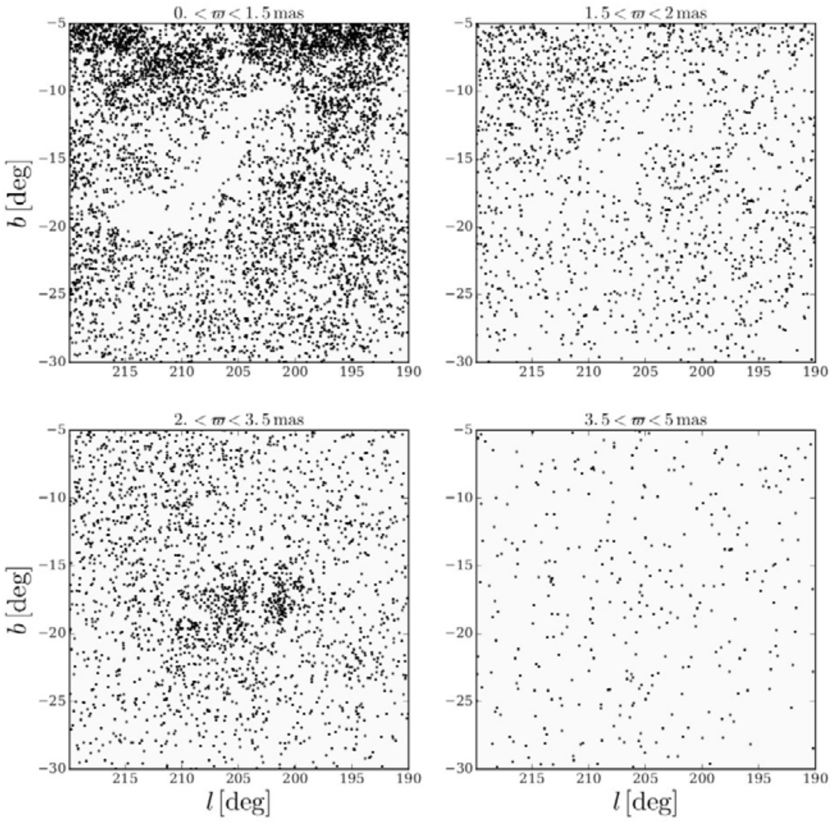


Fig. 4: The distribution of TGAS sources in the region of the sky around the Orion constellation. The four panels show the source distributions for different parallax ranges. In the upper left panel the contours of the Orion A and B molecular clouds are seen against the backdrop of distant stars (which increase in number toward the Galactic plane). The lower left panel shows a concentrated group of stars around a parallax of ~3 mas, which represent the bright end of an extended young population in Orion. Credits: Eleonora Zari.

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Gaia Collaboration, Brown A.G.A., Vallenari A., Prusti T., de Bruijne J.H.J, Mignard F., and 586 co-authors, 2016b, A&A, 595, A2

Gould A., 2004, ArXiv e-prints [arXiv:astro-ph/0403506] van der Marel R.P., Sahlmann J., 2016, ApJ, 832, L23

COMETS – Complex Organic Molecules on Extra-Terrestrial Surfaces

Harold Linnartz

Observational studies reveal that complex organic molecules (COMs) – molecules with more than 6 atoms (typically H, C, O, N or S) - can be found in various objects associated with different star formation stages. The recent identification of COMs in pre-stellar cores, *i.e.*, cold environments in which thermally induced chemistry can be excluded and radiolysis is limited by cosmic ray induced UV-photons, is particularly important as this stage sets up the initial chemical composition from which ultimately stars and planets evolve. In the Sackler Laboratory for Astrophysicis we have studied in detail the processes that lead to the formation of complex organic molecules under interstellar conditions. For this we use different experimental setups, like SURFRESIDE2, CRYOPAD2 or MATRI2CES, ultra-high vacuum (better than 10-10 mbar) and cryogenic (10-15K) setups that all are fully dedicated to the study of dynamical processes in interstellar ice analogues. CRYOPAD2 and MATRI2CES allow to investigate physical and chemical processes upon irradiation with harsh UV photons (120-180 nm), as present in the diffuse interstellar medium or arising from a young stellar object in proto-planetary disks.

Fig. 1: SURFRESIDE2, a sophisticated cryogenic ultra-high vacuum setup in which atoms impacting on an interstellar ice analogue are used to increase molecular complexity in the solid state.

With SURFRESIDE2 it is possible to grow interstellar ice analogues and in parallel, to bombard these with free atoms (H, D, N, or O) that trigger new reactions upon impact, merging precursor species and reactive intermediates through surface diffusion processes. In 2015 we demonstrated that molecules as complex as glycolaldehyde and ethylene glycol are efficiently formed on icy dust grains via non-energetic atom addition reactions between accreting H atoms and CO-molecules [Chuang et al. 2016], a process that dominates surface chemistry during the 'CO-freeze out stage' in dense cores, when icy dust grains are covered by a CO-coating. In 2016, we showed that a similar mechanism results in the formation of the biologically relevant molecule glycerol - $H_2C(OH)(HCOH)CH_2OH$ – a three-carbon bearing sugar alcohol necessary for the formation of membranes of modern living cells and organelles (Fedoseev et al., 2017). Key in the formation of new COMs is the mechanism that extends, for interstellar conditions, the size of a carbon backbone of the precursor molecule with new C-C bonds. In our work we showed that this can be realized through recombination of C-atom containing radicals, like HCO or CH_2OH, reactive intermediates that are formed along the hydrogenation from CO to methanol. This is illustrated in the reaction diagram.
On the left side, in the inner circle, the CO-H_2CO-CH_3OH reaction pathway is shown, as well as the involved HCO and CH_2OH radicals (Fuchs et al. 2009). Recombination of these radicals allows the formation of sugars and sugar alcohols, like ethylene glycol and glycol aldehyde. Recombination of such a reaction product with another radical, results in the next larger member in the sequence, glycerol and glyceraldehyde. Combining highly sensitive diagnostic tools, like temperature programmed desorption mass spectrometry and Fourier transform infrared spectroscopy or laser ablation time-of-flight mass spectrometry, and performing isotopic control experiments we have been able to unambiguously proof for a first time the formation or larger COMs under dark cloud conditions.

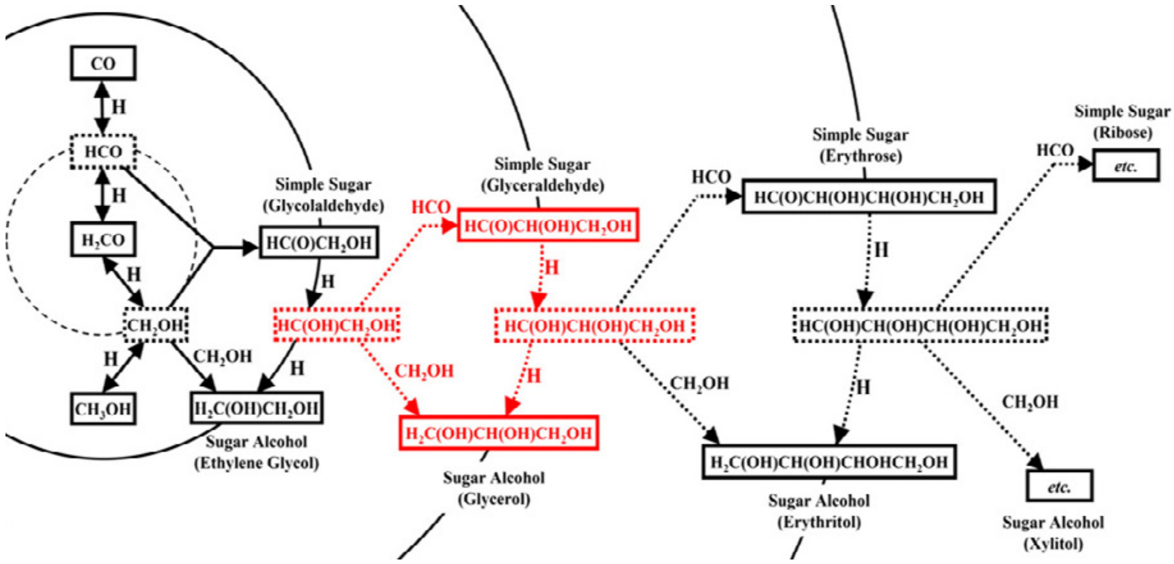

Fig. 2: Reaction diagram showing how H-atom additions to CO, one of the most abundant ice constituents, allow to form rather complex molecules, such as sugars and sugar alcohols.

The astronomical importance of our experimental findings is emphasized by the astrobiological role of the obtained species. Glycerol is a necessary component of phospholipids (consisting of fatty acids, glycerol and inorganic phosphate) comprising the membranes of living cells. Glyceraldehyde is the simplest sugar that plays a key role in the energy transfer inside the cells of living organisms. Furthermore, the formation of glycerol and glyceraldehyde along the steps discussed here means that even larger sugar and sugar alcohols are expected to be formed by hydrogenation of accreting CO molecules, as shown in the right part of the reaction diagram. Thus, the presence of simple sugars and sugar alcohols on young planets is possible under the assumption that at least a fraction of the original icy-dust material survives upon transfer to the early planet surface or, alternatively, is delivered by comets or other extra-terrestrial bodies during the late bombardment stage of the early Earth. The results also show that prebiotic species can form in dark interstellar clouds, far before the actual star and planet formation start. This is an important finding that is fully in line with the detection of COMs on comet P67/C-G or in meteorite samples.

The big challenge for the next years is to link COM formation in ices to COMs observed in the gas phase. Linking COM gas phase spectra recorded with ALMA and solid state features with JWST to laboratory and modelling studies will allow to bridge the grain-gas gap. First results obtained in 2016 (Bertin et al. 2016) show that UV radiation plays a much smaller role than expected, and also the effect of thermally induced co-desorption can be largely neglected. (Something else must be going on... please read the annual report of 2017).

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H-atom addition and abstraction reactions in mixed CO, H2CO and CH3OH ices; An extended view on complex organic molecule formation; K.-J. Chuang, G. Fedoseev, S. Ioppolo, E.F. van Dishoeck, H. Linnartz, 2016, MNRAS, 455, 1702.

Formation of Glycerol through Hydrogenation of CO ice under Prestellar Core Conditions; G. Fedoseev, K.-J. Chuang, S. Ioppolo, D. Qasim, E.F. van Dishoeck, H. Linnartz, (2017) ApJ, in press.

UV photodesorption of methanol in pure and CO-rich ices; desorption rates of the intact molecule and of the photofragments; M. Bertin, C. Romanzin, M. Doronin, L. Philippe, P. Jeseck, N. Ligterink, H. Linnartz, X. Michaut, J.-H. Fillion, 2016, ApJL, 817, L12.

The **search** for **extraterrestrial life**

Ignas Snellen

ERC Advanced Grant winner 2016

The central objective of studying extrasolar planets is understanding the place of the solar system in the context of other planetary systems. One of the most fascinating questions is whether other life-bearing planets exist. Progress has been impressive. Barely 25 years ago the first exoplanets were discovered, while we now know of thousands of planets orbiting other stars. Two important lessons have been learned. Firstly, planets are everywhere. While gas giants like Jupiter are found around at least 1 in 10 stars – most stars turn out to have Earth-mass planets. Secondly, the planet diversity is enormous. Gas giants are found in very unexpected places, such as hot Jupiters in extremely close-in orbits, as well as hundreds of astronomical units from their host stars. Currently, the most commonly found planets have masses between that of the Earth and Neptune. Dubbed super-Earths, they form a class of planet that is not even present in our own solar system.

In 2016, an important milestone was reached with the discovery of Proxima b by Guillem Anglada-Escudé (Queen Mary University London) and his team - a planet only 30% more massive than Earth and possibly with a climate that is in some ways like ours. It may be our prime laboratory for the search for extraterrestrial life in the coming decade. Our research is centered on learning how we could find evidence for biological activity on extrasolar planets like Proxima b, which forms the focus of my ERC Advanced Grant project.

Already more than half a century ago it was suggested by James Lovelock that evidence for extraterrestrial life could be obtained via the detection of biomarker gases – molecular species out of thermodynamic equilibrium which are not expected to be present in the planet atmosphere. A good example is molecular oxygen in the Earth atmosphere which only exist because it is produced by life as waste product. Finding molecular oxygen in an Earth-like atmosphere, in particular in combination with methane, could serve as a first hint of extraterrestrial biological activity.

However, such claim will only be possible if we really understand atmospheric processes and their evolutionary histories, which can only be achieved through detailed studies of a wide range of planets, from gas giants to rocky planets in a wide range of orbits around stars varying in mass, metallicity, and age.

In my group, we pioneer observational techniques to study exoplanet atmospheres, in particular to determine their constituencies, thermal structure, and constrain their global circulation patterns and bulk rotation – the main parameters that govern a planet's climate. While now thousands of exoplanets have been discovered, most of them have been found without identifying a single photon from the planets themselves. For atmospheric observations this can no longer be the case – the planet light needs to be separated from that of the star.

There are two families of techniques in use. One utilizes the temporal variability of the planet light to separate it from the star – in particular transits and secondary eclipses. When as seen from earth a planet is moving in front of its star, it not only blocks part of the stellar surface, a small fraction of the starlight filters through the planet atmosphere leaving an imprint of absorption from the gases present. By comparing the star+planet spectrum during the transit with that just before and/or after the planet absorption can be measured and atmospheric species identified. Half an orbit later the planet is eclipsed by the star. The light lacking during the eclipse is the intrinsic spectrum of the planet revealing its temperature and atmospheric structure.

The second family of methods uses an angular separation of the planet from the star on the sky, called direct- or high-contrast imaging, obtaining the sharpest possible image while suppressing starlight using coronagraphy. While the transit/eclipse method work best for hot close-in planets, the direct imaging method is most sensitive to young gas-giants far away from their star which are still warm from their formation.

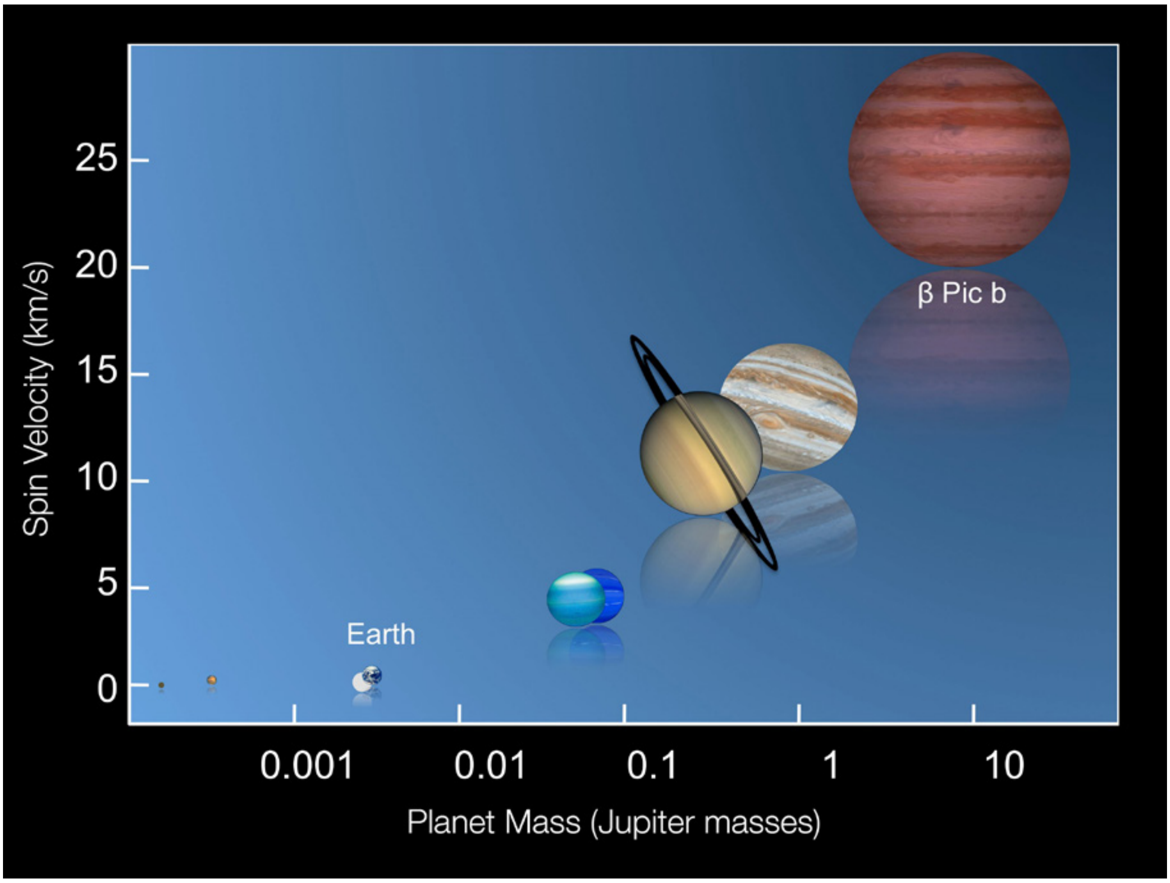


Fig. 1: Relation between the spin velocity and mass of the solar system planets and Beta Pictoris b.

Leiden methods

The methods we pioneer in Leiden use the above techniques in combination with high-dispersion spectroscopy – measuring the spectrum of the incoming light to a precision of 1/100,000th of a wavelength. The high-dispersion spectroscopy is a crucial addition to make the above techniques particularly sensitive for ground-based telescopes, like the Very Large Telescope (VLT) at the European Southern Observatory – and later the European Extremely Large Telescope (E-ELT). At high-dispersion the planet spectrum is not only significantly different from that of the star and the Earth atmosphere through which we need to do our observations, due to the motion of the Earth around the Sun, that of the planet around its star, and that of the sun and the star through the galaxy, the radial velocity of the planet light is in general significantly non-zero and variable. This is utilized to further separate the planet signals from that of the star and our own atmosphere.

Molecules and atmospheric dynamics

We obtained the first success with this technique targeting carbon monoxide in the transmission spectrum of the hot Jupiter HD209458 b using the CRIRES spectrograph on the Very Large Telescope of the European Southern Observatory in Chile back in 2010. We were also the first to detect the same molecule in a non-transiting planet – tau Bootis – using the same instrument, solving for the first time for the orbital inclination and mass of a non-transiting hot Jupiter, and also detected water in this way. Recently, we measured for the first time the rotation velocity of an extrasolar planet - the directly imaged young gas-giant β Pictoris b - showing it to spin much fast than the gas giants in our own Solar system and deriving the length of day of the planet to be ~8 hours.

Currently, the CRIRES instrument is undergoing an important upgrade. It will get new, more sensitive detectors and a so-called cross-disperser which will increase the instantaneous wavelength coverage by more than an order of magnitude. The upgraded instrument, CRIRES+, is expected to be available from the second quarter of 2018 and will provide an enormous leap forward in atmospheric observations of extrasolar planets. As part of the ERC project we will make a large inventory of planet spin rates as function of planet mass and age and for the first time shed light on how planets acquire angular momentum during formation. We will probe the atmospheres of much cooler planets than now, and will be able to probe molecular signatures above their cloud decks – which are currently hampering detections. The thermal atmospheric structures of hot Jupiters will be determined in detail, revealing their vertical and longitudinal atmospheric temperature profiles, and obtain a complete inventory of their C and O bearing molecules. Hopefully, we can also for the first time constrain isotope ratios for these targets – giving insights in their evolutionary histories.

The future is extremely large

While playing around with the newest tricks on the VLT, we are preparing ourselves for the new giant of European astronomy – the European Extremely Large Telescope – which will have a mirror diameter of 39 meters. The amount of observing time needed for some of the methods described above scale with the diameter of the telescope to the fourth power, meaning that the E-ELT will be 500 times faster than the VLT. This will bring Earth-like planets into reach. For example, the atmosphere of the newly discovered planet Proxima b will be easily detectable with the first-light instrument METIS, of which NOVA is the PI-institute and our own Bernhard Brandl its principle investigator. Exciting times ahead!

Fig. 2: Artist's impression of Proxima b (credit: ESO).

PhD Degrees

List of **PhD degrees awarded** at Leiden Observatory in **2016**.

Name	Date	Supervisor	Thesis Title
C.M.S. Straatman	29-03	Labbé	Early death of massive galaxies in the distant universe
A.J. Rimoldi	29-03	Portegies Zwart	The influence of dramatic stellar events on their environment
N. Lopez Gonzaga	12-04	Jaffe	The structure of the dusty cores of active galactic nuclei
C.A. Martinez Barbosa	13-04	Brown	Tracing the journey of the Sun and the solar siblings
A.S. Hamers	21-06	Portegies Zwart	Hierarchical Systems
D.M. Paardekooper	05-07	Linnartz	Shining Light on Interstellar Matter
C.J. Sifon	07-09	Hoekstra	The Connection Between Mass and Light in Galaxy Clusters
L.K. Morabito	13-09	Röttgering	Radio Galaxies at Low Frequencies: high spatial and spectral resolution studies with LOFAR
A. Feldmeier-Krause	13-09	De Zeeuw	The Assembly History of the Milky Way Nuclear Star Cluster
F. Koehlinger	29-09	Kuijken	Weighing the Dark: Cosmological Applications of Gravitational Lensing
L.D. di Gesu	04-10	Kaastra	Winds in the AGN environment: new perspectives from high-resolution X-ray spectroscopy
M.N. Drozdovskaya	06-10	Van Dishoeck	Inextricable Ties Between Chemical Complexity And Dynamics Of Embedded Protostellar Regions
G.P.P.L. Otten	29-11	Kenworthy	Suppressing a sea of starlight: Enabling technology for the direct imaging of exoplanets
J. Franse	20-12	Kuijken/Achucarro	Hunting Dark matter with X-rays

List of **PhD degrees awarded** at Leiden Observatory in **2015**.
(missing in last year's Annual Report).

Name	Date	Supervisor	Thesis Title
D. P. Caputo	22-01	Portegies Zwart	The Great Collapse
V. Cuylle	29-01	Linnartz	Hydrocarbons in Interstellar Ice Analogues
Xiaohu Li	12-02	van Dishoeck	Molecules during Stellar Formation and Death
R. Smit	28-04	Bouwens,Franx	Star Forming Galaxies at the Cosmic Dawn
S. Krijt	29-04	Tielens,Dominik	From Grains to Planetesimals: the Microphysics
A.L.M. Lamberts	20-05	Linnartz	Unraveling the Surface Formation of regular and deuterated Water in Space
M.V. Khazandian	03-06	Israel, Meyerink	Diagnostics of Mecanical Heating in Star Forming
T. Meshkat	11-06	Kenworthy	Extrasolar Planet Detection through Spatially resolved Observations
I. San Jose Garcia	18-06	van Dishoeck, van der Tak	Formation: Dynamics probed by Herschel Far Infrared Spectroscopy
B. Ochsendorf	01-09	Tielens	Tales of Orion:the Interplay of Gas, Dust and Stars in the interstellar Medium
A. Stroe	02-09	Röttgering	When Galaxy Clusters Collide: the Ipact of Merger Shocks on Cluster Gas and Galaxy Evolution
F. Salgado Cambiazo	02-09	Tielens	Study of Dust and GAs in the Interstellar Medium of the Milky Way
M. Fumagalli	08-09	Franx	Star Formation and Aging at Cosmic Dawn: the Spectral Evolution of Galaxies for z=2
N. v.d. Marel	29-09	van Dishoeck	Mind the Gap: Gas and Dust in Planet Forming Disks (Cum Laude)

List of **PhD degrees awarded** at Leiden Observatory in **2015**.
(missing in last year's Annual Report).

Name	Date	Supervisor	Thesis Title
P. Russo	10-11	van den Broek, Miley	Design, Implementation and Evaluation of Transnational Collaborative Programmes in Astronomy Education and Public Outreach
T.C.N. Boekholt	10-11	Portegies Zwart	Chaotic Dynamics in N-body Systems
M. Velliscig	11-11	Schaye	Probing the Darkness: the Link between Baryons and Dark Matter
A. Richings	08-12	Schaye	Non Equilibrium Chemistry and Cooling in Simulations of Galaxy formnation
M. Turner	12-11	Schaye	Metals in the Diffuse Gas aroung high Redshift Galaxies
W. Williams	10-12	Röttgering	Facets of Radio Loud AGN Evolution: a LOFAR Surveys Perspective
A. Elbers	10-12	van Lunteren, Israel	Early Dutch Radio Astronomy (1940-1970): the People and the Politics
C. Shneider	17-12	Haverkorn	Reconstructing Magnetic Fields of Spiral Galaxies from Radio Polarimetric Observations

Publications

Over the year 2016, scientists at Leiden Observatory have published a total of 466 articles in international refereed journals. Astronomy & Astrophysics (112 articles; impact factor 4.378), the Astrophysical Journal (130 articles; impact factor 5.909), and the Monthly Notices of the Royal Astronomical Society (142 articles; impact factor 5.521) published together 82% of all papers. The complete list can be found at https://local.strw.leidenuniv.nl/annual-reports/annualreport.php

Interview: **The academic mothers of Leiden Observatory**

By Iris Nijman

Academic mothers are still seen as something special. Not many women choose to give birth during the most crucial and challenging years of their career. But times are changing: in 2016, four female astronomers of Leiden Observatory have given birth. “It can be done,” is what they all say. But how? What are the keys to success? And how can academic parents be more supported?

The mothers

Elena Maria Rossi (Associate professor)
Elena from Italy is the first female staff member in the history of Leiden Observatory who became a mother during her career. Her first daughter Alma was born in 2014, and in 2016 she gave birth to Sofia. She has been living in the Netherlands since 2011.

Alessandra Candian (Postdoc)
The Italian Alessandra moved to the Netherlands for a postdoc at Leiden Observatory in 2012. She gave birth to Viola in 2016.

Caroline D'Angelo (Postdoc)
Caroline from Canada has been a postdoc at Leiden Observatory since 2014. In 2016, she gave birth to Alexía.

Anna Miotello (PhD-student)
Anna from Italy gave birth to Caterina during the first year of her PhD in Munich in 2014. She has been doing the next three years of her PhD at Leiden Observatory. Her second child, Ambrogio, was born in 2016.

Did you hesitate to have children during your academic career?

Elena: “I met my partner when we were both working in Israel. In 2011, I got a tenure track in the Netherlands and my partner came two years later. In 2017, I got a permanent position in Leiden. I had two kids during the probation period, which is very rare. Usually women try to have kids after they got a permanent position. But I thought I could do it before that time. I was ready, but the question was whether the system was ready for it. I wanted to try and see.”

Alessandra: “There is no perfect time to have children. I always thought I would have children at some point, but during my PhD my partner was living in another country. When I got a Veni grant to work for three years in Leiden, we both felt it was a stable enough situation to have a child.”

Caroline: “I didn’t want to allow my career to interfere with my personal life too much. I knew that I had a temporary job, but I felt that we were settled enough to make it work. The fact that I am in academics shouldn’t be a reason to wait.”

Anna: “Having kids is not as plannable as one might think. When my husband and I got married, we were open to have kids. We were both PhD students, but we have never seen this as an obstacle to having kids. People always ask me what it is like to do a PhD with kids, but I don’t know what it is like to do it without them.”

What are the keys to success?

Organise

Elena: “My workdays are shorter and I don’t work outside office hours, so I need to delegate more. I am leading projects, but the practical work is done by my students. Also, I prioritise my work very carefully: I only invest my energy in the most important projects. This works very well.”

Alessandra: “My workdays are shorter, because I need to pick up Viola from day care at 5 PM. And that means I need to be more efficient. I have realised that I am much more productive now than I ever was before I got a child.”

Anna: “Having kids helps me to be more efficient. I am motivated to exploit all the time I have at work to be able to be with my children later.”

Be self-confident

Elena: "Whatever you manage to do, is enough. It's very important to be self-confident, optimistic and don't question the amount of work you can do."

Caroline: "I am not less ambitious in my career because I had a child."

Anna: "When I was pregnant, I didn't know if I would like my work as much as before. But as soon as I had my daughter, I realised that I really wanted to stay in academia."

Support from partners

Alessandra: "My partner has the same job and takes 50 percent of the care. Otherwise it would not have been possible."

Elena: "I could not have done it without the full support from my partner."

Anna: "My husband and I have the same job, so we know what we need from each other to be able to work and take care of our children at the same time. He supports me."

Support from the work environment

Elena: "The Observatory offered me a coach who taught me how to prioritise, manage my time and students, and how to ask for support."

Alessandra: "My supervisor supports me a lot. Also, the Observatory helped me to get an extension of my contract for the four months that I was on maternity leave. Which is special, because the new law for fixed-term contract doesn't automatically grant that to postdocs."

Caroline: "The attitude towards new mothers is very good. I got sick early during my pregnancy, so I had to take part-time leave earlier than expected. But the Observatory was really supportive and understanding and helped me arrange my leave and a bit of extra partially paid time off afterwards. Now that extra time is added to my contract. That made a huge difference for me."

Anna: "Without my supportive supervisor I would not have been able to do my PhD and be a mother. I have never felt judged for my choice to be mother. My supervisor has always helped me to find practical solutions and she never asked me to travel when my kids were very young. Thanks to that, I never felt like I was missing something important."

Diversity committee

All four women have been part of the Diversity Committee of Leiden Observatory, which was set up by Elena in 2012. The Committee addresses the key challenges for minorities in the institute, like academic mothers. These challenges were identified using a questionnaire. One of the main realisations of the Committee is the new breastfeeding/pumping room. The Committee also organises workshops and colloquia. Coming year, the Committee wants to spread another questionnaire and continues to organise colloquia.

What are the main challenges for academic motherhood?

Judgement of performance

Elena: "When you apply for jobs, you are judged on the amount of papers you wrote. So then having children works against you, if you can't work fulltime. There is no generally accepted protocol on how to compare men that work fulltime, with women who had children during her career. Moreover, future employers generally presuppose that a mother will be less efficient and less committed than a single man, or a dad."

Alessandra: "There's a study[1] that shows that academic fathers are perceived as more reliable and dedicated than academic mothers. I also experience this sometimes, because I do not spend the same amount of time at work as before."

Physical effects

Elena: "I underestimated the lack of sleep. Some days I was so tired that I had to prioritise my work in a way that I could do things that didn't require a lot of attention. I was not alert enough to study or do complicated calculations."

Alessandra: "I was also more tired than I expected beforehand."

Caroline: "I was nauseous a lot while I was pregnant, which affected my productivity."

1 Correll, S., Benard, S., & Paik, I. (2007). Getting a Job: Is There a Motherhood Penalty? American Journal of Sociology, 112(5), 1297-1338. doi:10.1086/303146

Travel/Conferences

Elena: "I sometimes have to refuse to go to conferences because they don't offer childcare. And the less you go to conferences, the less they ask you to go. They forget about you."

Alessandra: "In the spring just after I gave birth to Viola, I was invited as a speaker to several conferences, but unfortunately I had to decline. I expected that I could go when she was three months old, but even then, it was too much to take long travels."

Caroline: "The most important things during conferences happen outside of the sessions. The chance to have scientific discussions with people over dinner of drinks. That's much more difficult if you have to bring your child."

What could be improved?

Inclusive hiring and parental leave

Elena: "I would like to be involved in developing a procedure for more inclusive hiring. As a department, we could already take some practical steps into that direction."

Alessandra: "At the governmental level, it would really help if maternal and paternal leave were equal. That may also help preventing the hiring bias."

Caroline: "Unfortunately my husband couldn't take paid time off, so he could help me less with the practical things. It would be good to have six months to divide between the mother and father."

Financial support and conferences

Elena: "There could be more money invested to support academic mothers. For example, to help ensuring supervision of students during maternity leave, and childcare at conferences."

Alessandra: "It would help if conferences had financial support to hire baby sitters or would think about nearby day care facilities. That really makes the difference if somebody could attend the conference or not."

Anna: "I have seen more cases in which both partners were astronomers and needed to attend the same conference. In those situations, child care is a very important aspect."

Family room

Alessandra: "Our original idea for the breastfeeding room was that it could also be a family room. A place for parents to be able to take their children in case they have to be at work and they can't leave their children with anybody else. This is especially valuable for PhDs and postdocs, who don't have a private office. The Observatory was very positive, but unfortunately the Faculty doesn't allow this family room yet due to safety issues."

Anna: "In Munich I had a single office, so I could take Caterina with me when needed. Here I don't, so a family room would have been very helpful."

Meeting time

Alessandra: "Sometimes I cannot attend conference calls or seminars because they are at times that I need to take care of my daughter. What could be done to help parents is to have those calls, meetings, seminars and colloquia between 10 AM and 4 PM."

Colloquia and Lectures

Scientific Colloquia
at Leiden Observatory

28 Jan: Floris van der Tak, *SRON Groningen*
The fuel for star formation in galaxies

04 Feb: Uwe Meierhenrich, *Universite Nice*
Rosetta - Landing and Science on a Cometary Nucleus

18 Feb: Gijs Nelemans, *Radboud Universiteit*
Gravitational-wave astrophysics: what is in it for us?

10 Mar: Mordecai MacLow, *Columbia University*
Formation and Evolution of Giant Molecular Clouds: Gravity or Turbulence?

23 Mar: Lennart Lindegren, *Lund University*
Billions of stars

24 Mar: Saskia Hekker, *MPI Solar System Research*
Asteroseismology of solar-like oscillators: recent results

32 Mar: Jose Cernicharo, *CSIC Madrid*
Molecular Complexity in the interstellar and circumstellar media; new molecular species, isotopologues, and vibrationally excited states

14 Apr: Thomas Tauris, *Angelander Institute Bonn*
Ultra-stripped supernovae: progenitors and fate

21 Apr: Hans-Walter Rix, *MPI Heidelberg*
How the Milky Way built its Disk

28 Apr: Luigi Guzzo, *INAF - Osservatorio di Brera, Milano/Merate*
The VIMOS Public Extragalactic Redshift Survey (VIPERS): a detailed view of large-scale structure and galaxies at z~1

07 Jun: Leonard Burtscher, *MPI extraterrestrial physics, Garching*
Diet for the monsters: molecular tori in active galaxies

09 Jun: Melissa McClure, *ESO, Garching*
Planetary building blocks in infrared

16 Jun: Denis Defrere, *University of Liege*
High-angular resolution infrared imaging of exoplanetary systems

20 Jun: Julien Girard, *ESO, Santiago, Chile*
Exoplanet exploration from the ground

27 Jun: Pierre Cox, *Joint ALMA Observatory, Santiago, Chile*
Atacama Large Millimeter/sub-millimeter Array (ALMA): Status and Development

07 July: Wouter Karman, *Universiteit Groningen*
Spectroscopic properties of high-z galaxies over a large range of stellar masses

12 Sep: Anja Feldmeier-Krause, *ESO Garching*
The Assembly History of the Milky Way nuclear star cluster

15 Sep: Ilya Mandel, *Birmingham*
Gravitational waves ...

22 Sep: Enrico Ramirez-Ruiz, *University of Santa Cruz*
Heavy element synthesis in the Universe

06 Oct: Clifford Will, *University of Florida*
Was Einstein Right?

13 Oct: Vernesa Smolcic, University of Zagred
The VLA-COSMOS 3 GHz Large Project: The dust-unbiased cosmic star formation history since z~6

10 Nov: Jean-Pierre Lasota-Hirszowicz, *IAP Paris*
Ultraluminous means super-Eddington

17 Nov: Inti Pelupessy, *Leiden*
Modelling the seas of Huygens' moon

01 Dec: Mathieu Ossendrijver, *Universitat Berlin*
Recent discoveries in Babylonian astronomical computation

08 Dec: Caitlin Casey, *University of Texas at Austin*
The Ubiquity of Coeval Starbursts in Massive Galaxy Cluster Progenitors

15 Dec: Ann Madigan, *JILA, University of Colorado, Boulder*
The Importance of being Eccentric

Endowed **Lectures**

The **Oort Lecture**

Prof. Joseph Silk,
Institut d' Astrophysique de Paris & Johns Hopkins University, Baltimore.

The Oort Lecture is an annual event, in memory of the famous Leiden astronomer, organized by the Jan Hendrik Oort foundation and Leiden Observatory. The lecture covers an astronomical subject of current interest and is intended for a mixed audience with a general interest in astronomy. This year's lecture was presented by Prof. Joseph Silk and took place in the Academic Building in Leiden on April 22.

Prof. Joseph Silk is one of the world's leading experts in theoretical cosmology, the cosmic microwave background, and dark matter, and an outstanding science communicator. He has done important work on density fluctuations in the early Universe, discovering a key mechanism in early structure formation, which is now called 'Silk damping' after him. A graduate of Cambridge and Harvard, he was at the University of California, Berkeley, for three decades, before moving to Oxford, where he was the Savilian Professor of Astronomy from 1999 to 2011. Currently, he is Professor of Physics at the Institut d' Astrophysique de Paris and Homewood Professor of Physics and Astronomy at The Johns Hopkins University in Baltimore. In 2011 he was awarded the Balzan prize, for his pioneering work on the infant Universe.

One of our greatest challenges is understanding the origin of the structure of the universe. Prof. Silk described how the fossil radiation from the beginning of the universe, the cosmic microwave background, has provided a window for probing the initial conditions from which

structure evolved. Infinitesimal variations in temperature on the sky provide the primordial fluctuations that seeded the formation of the galaxies. He discussed how one might follow up on the Planck satellite which has given us remarkable maps of the microwave sky that complement galaxy surveys, and support the standard model of cosmology to high precision. However, a number of fundamental issues remain unresolved. He discussed the optimal choice of future strategy in order to make further progress.

The **Sackler Lecture**

Prof. Sarah Bridle,
University of Manchester

The Raymond and Beverly Sackler Lecture 2016 was held on November 24st and given by Professor Sarah Bridle. Sarah Bridle is Professor of Astrophysics in the Extragalactic Astronomy and Cosmology research group of the Jodrell Bank Center for Astrophysics in the School of Physics and Astronomy at The University of Manchester. She is a world expert on measuring and interpreting the 'weak gravitational lensing' effect, a subtle distortion of the light from distant galaxies due to intervening mass distributions. She is co-coordinator of the Weak Lensing Science Working Group of the Dark Energy Survey, and project scientist for the UK consortium in the Large Synoptic Survey Telescope.

In addition to her work on cosmology, Sarah Bridle is also developing ways in which image processing and data science expertise in cosmology can be applied to Earth observation studies, in particular in relation to sustainable food production.

Prof. Bridle's lecture was entitled *'Quantifying Dark Energy using Cosmic Lensing'*, in which she described the great potential and limitations of using the bending of light by gravity (gravitational lensing) to constrain

the mysterious dark energy which seems to dominate the contents of our Universe. In particular, she described how to remove the blurring effects of telescopes and the atmosphere to extreme precision, and account for possibly coherent distortions of galaxy shapes due to processes in galaxy formation. She discussed these issues in detail and reviewed some recent progress in tackling them, including in the context of recent results from the Dark Energy Survey.

PhD Colloquia

14 Jan: Pedro Russo
How to engage and educate the global public with astronomy

21 Jan: Noel Lopez Gonzaga
The Dusty Cores of Active Galactic Nuclei

11 Feb: Gilles Otten
Suppressing a Sea of Starlight: enabling technology for the direct imaging of exoplanets

11 Feb: Caroline Straatman
A generation gap: early granny-fication in the high redshift universe and kinematics of massive galaxies

17 Mar: Alex Rimoldi
Clues from stellar catastrophes

07 Apr: Astrid Elbers
The history of radio astronomy in the Netherlands between 1940 and 1970

12 May: Adrian Hamers
Hierarchical systems -- applications to Hot Jupiters

19 May: Daniel Paardekooper
Shining light on interstellar matter

23 Jun: Cristóbal Sifon
The connection between mass and light in cluster galaxies

01 Sep: Maria Drozdovskaya
Inextricable ties between chemical complexity and dynamics of embedded protostellar regions

06 Sep: Leah Morabito
Radio Galaxies at Low Frequencies: high spatial and spectral resolution studies with LOFAR

08 Sep: Fabian Kohlinger
Weighing the Dark: Cosmological Applications of Gravitational Lensing

27 Oct: Edwin van der Helm
Blown away: Stellar mass loss and mass transfer in dense stellar systems

29 Nov: Henriette Schwarz
Spinning Worlds

06 Dec: Jeroen Franse
Hunting Dark Matter with X-Raysr

Education

Bachelor and Master in Astronomy

Teaching and training of students is a major priority of Leiden Observatory, which offers both a university bachelor (BSc) and master (MSc) programme in astronomy.

The BSc programme is 3 years and is partly taught in Dutch, with combinations of lectures, problem classes, and practical work. In addition to astronomy courses, the programme consists of a significant fraction of courses in mathematics, physics, and informatics. First year students conduct their first astronomical observations with the modern LUF/Gratama telescope on the roof of the historic observatory building in the centre of Leiden, and learn about coordinate systems during a lecture at the planetarium in Artis, Amsterdam. In years two and three the emphasis is increasingly on astronomy. Highlights include observations at the 2.5m Isaac Newton Telescope on La Palma (Canary Islands, Spain) carried out and analysed by the students, and the 6-months research project at the end of their BSc.

The MSc programme is 2 years and taught fully in English, attracting also many foreign students. Education and research focus on three major themes: (i) the formation and evolution of galaxies, (ii) the birth of stars and planets, and (iii) cutting-edge instrumentation. The astrochemistry and optics laboratories, and high performance computing facilities also function as training grounds for students, and are used for student's research projects. Students graduate with a broad knowledge of astronomy and astrophysics, but may specialise in various fields. In addition to the general research master, the MSc programme in Astronomy offered six specialisations:

1. Astronomy and Cosmology
2. Astronomy and Instrumentation
3. Astronomy and Data Science
4. Astronomy and Education
5. Astronomy and Science-Based Business
6. Astronomy and Science Communication and Society

Student **Numbers**

Student numbers, which have been increasing since several years, continue to rise. In 2016, an exceptionally high number of 118 freshmen started their studies in the Astronomy BSc. Of this number, 37 (31%) were women, and 59 (50%) pursued a combined astronomy/physics or astronomy/mathematics/ computer science degree. The Observatory registered a total number of 204 BSc students at the end of the year, of which 72 (50%) aimed at a combined astronomy/physics degree or astronomy/ mathematics degree; 28% of all BSc students are female. There were 57 MSc students, including 15 (26%) women and 24 (42%) of foreign nationality.

Organisation

The entire teaching program is organized by the Education Office Astronomy (EOA), which deals with all aspects of the curriculum, including student support, outreach and internationalization. The EOA team currently consists of a Director of Education, Head of Education Office Astronomy & Programme Coordinator, Study Advisor, PR Education Coordinator, Internationalisation PR Officer, Education & Student Affairs Officer and a Secretary.

In addition to counseling by the student adviser, incoming students were assigned to small groups meeting at regular intervals with a staff mentor and a senior student mentor. In the tutor programme, physics and astronomy freshman students were provided on a voluntary but regular basis with coaching by senior students.

In the BSc programme, students in the 2nd and 3rd year write a Study Plan, which must be approved by the Study Advisor. The astronomy curriculum is monitored by the Education committee (Opleidingscommissie), which advises the Director of Studies on all relevant matters, and which was chaired by Linnartz. Under the authority of the Education Committee, the lecture course monitoring system was continued. In this system, students provide feedback to lecturers during and after the course.

In the MSc programme, the Astronomy & Data Sciences specialisation started and resulted in a number of new courses in the MSc programme. Quality control of all aspects of the exams is the responsibility of the Board of Examiners (Examencommissie) chaired by Snellen. Admission to the master-curriculum for students without a BSc in astronomy from a Dutch university requires a recommendation by the Admissions Committee (Toelatingscommissie) chaired by Schrier and having Portegies Zwart, Kuijken, Hogerheijde, and Kenworthy as members.

Academic **courses** and **pre-university Programmes**

BSc Courses

Title	Semester	Lecturer
Introduction astrophysics	1	I. Snellen
Planetary systems	2	H. Linnartz
Astronomy lab 1	2	M. Hogerheijde
Modern astronomical research	3	S. Portegies Zwart
Stars	4	H. Röttgering
Galaxies and Cosmology	4	J. Hodge
Astronomy lab 2	4	J. Brinchmann
Astronomical Observational techniques	5	C. Keller
Radiative processes	5	E. Rossi
Introduction General Relativity and Astrophysical Applications	5	P. van der Werf
Bachelor research project	5-6	K. Kuijken

MSc Courses

Title	Lecturer
Astrochemistry	Van Dishoeck
Astronomy from Space	Fridlund
Computational Astrophysics	Portegies Zwart
Detection of Light a + b	Brandl
Large Scale Structure and Galaxy Formation	Schaye
Inter Academic College (Gravitational wave astrophysics)	Various
Star and Planet Formation	Van Dishoeck
Stellar Structure and Evolution	Tielens
Astronomical Telescopes and Instruments	Keller/Kenworthy
Galaxies: structures, dynamics and evolution	Bouwens
Introduction Master Astronomy	van der Werf
Interstellar Medium	Tielens
Origin and Evolution of the Universe	Hoekstra
Observational High-energy Astrophysics	Winkler

Degrees **awarded** in **2016**

BSC DEGREES

A total of **18 students** obtained their **Bachelor's degree**:

Name	Date	Present Position
Vivienne Kolman	29-07-16	Travelling, MSc Astronomy Leiden
Irene Haasnoot	29-07-16	Travelling, MSc Astronomy Leiden
Damien Cornel	29-07-16	MSc Physics, Amsterdam
Iosto Fodde	29-07-16	MSc Aerospace Engineering, TU Delft
Nashwan Sabti	29-07-16	MSc Physics, Leiden
Dennis Vaendel	29-07-16	MSc Astronomy, Leiden
Lennart van Sluijs	29-07-16	MSc Astronomy, Leiden
Esmee Stoop	31-08-16	MSc Astronomy, Leiden
Michelle Willebrands	31-08-16	MSc Astronomy, Leiden
Steven de Rond	30-08-16	MSc Astronomy, Leiden
Charlotte Brand	29-07-16	MSc Astronomy, Leiden
Job van der Wardt	31-08-16	MSc Astronomy, Leiden
Marco Trueba van den Boom	31-08-16	MSc Astronomy, Leiden
Dylan Natoewal	30-08-16	MSc Astronomy, Leiden
Dominique Petit de la Roche	31-08-16	MSc Astronomy, Leiden
Guus de Wit	31-08-16	MSc Mathematics Leide
Brecht Simon	29-07-16	MSc Physics, Leiden
Willem Tromp	31-08-16	MSc Physics, Leiden

MSC DEGREES

The following **16 students** were **awarded Master's degrees**:

Name	Date	Present Position
Pim Overgaauw	29-07-16	Education and Student Affairs officer at Leiden Observatory
Manoressy Tobias Bumbungan	29-07-16	Job searching
Leindert Boogaard	29-07-16	PhD at Leiden Observatory
Leon Trapman	29-07-16	PhD at Leiden Observatory
David Doelman	29-07-16	PhD at Leiden Observatory
Kuldeep Sharma	29-07-16	Prospective PhD at Indian Space Research Organisation
Bart Verhaar	29-07-16	Software developer at TopDesk Delft
Qian Qian Lin	30-08-16	Job searching
Arthur Jakobs	31-08-16	Research Assistent Leiden Science, UBC Vancouver
Nikki Zabel	31-08-16	Alumni researcher at NOVA; PhD at Cardiff
Bavo Croiset	31-08-16	ASML
Mathias Veenman	31-08-16	Data Scientist at Eneco Energy Trade B.V.
David Bekkers	31-08-16	Innovation, Technology & Science Officer at Dutch Embassy in Beijing
Emiel Por	31-08-16	PhD at Leiden Observatory
Kasper van Dam	31-08-16	PhD at Nikhef in Amsterdam
Darren Buttigieg	31-08-16	Software developer at Sherpa MSL

Outreach and popularisation

Pre-university programme

LAPP-Top, the Leiden Advanced Pre-University Programme for Top Students, is aimed at enthusiastic and ambitious high-school students from the 5th and the 6th grade. Candidates are selected on the basis of their high-school grades and their enthusiasm to participate, as shown by a letter of motivation. Students that are selected then take part in 6 to 8 meetings from January till May, following the programme of their own choice.

The Sterrewacht has been participating in the LAPP-TOP programme since its start in 2001. In that pilot year 5 students participated, growing to an average of 28 students over the years. In eight sessions the following subjects were covered: The Milky Way and other galaxies, Extrasolar planets, Building molecules and planets in the universe, Practicum I + II, Black Holes, Cosmology and an excursion to the radio telescopes in Westerbork and Dwingeloo.

After successfully completing the programme participants have been awarded a certificate from the University of Leiden. High- school students are allowed to use this project as part of their final exams.

Contact.**VWO**

Contact.VWO (Contact-punt-VWO) is the liaison between pre-university education and the Departments of Astronomy and Physics at the University of Leiden. It supports both teachers and their students with various activities. Since the start in 2008, Contact.VWO has built a significant network of more than 500 teachers over the entire country, through which a multitude of high school students is reached. Various activities are defined through which this network is fed:

- **Teacher meetings:** These meetings are organized three times per year, according to a fixed format: Start at 1700 pm, end at 2030 pm. The meetings start with a plenary session, a scientific contribution from one of the staff members. This is followed by a dinner. The evenings continue with a plenary session with many smaller contributions. Meetings are attended by seventy participants on average.
- **Einstein's Birthday:** We celebrate Einstein's birthday (March, 14th) with a seminar for both teachers and their best students. We welcome our visitors with challenging scientific contributions from the staff, followed by lab visits (30 teachers; 80 students).

- **HiSPARC:** This is the Dutch project for high-energy physics and cosmology education which is an optional subject in the new physics curriculum for pre-university levels. Contact.VWO is a regional partner for this project. We support more than ten schools in our network.
- **Profielwerkstuk support:** For their final assignment (profielwerkstuk) high school students spend 80 hours researching a field of their interest. Highly motivated students can apply for our support. Yearly we coach about 50 high school students with a subject in physics or astronomy.
- **Experiments for Quantum-world:** Recently, the physics curriculum for pre-university level has been renewed. It now includes sections on quantum-world and astronomy, including radiation processes. We designed a set of fifteen challenging experiments to support these new subjects. We use professional equipment that is not generally available for high schools. The experiments can be performed by individual students, or by a visiting class.
- **Visits of school classes:** Contact.VWO has two programs in which visiting school classes can perform a practical assignment. “Discover Exoplanets” and “Quantum World”. We include a lunch-seminar in these visits. These seminars are given by PhD students. This year more than twenty schools visited these programs.
- **Posters:** Twice a year 250 schools in our region receive two posters. The posters highlight a research novelty and announce upcoming events.

Astronomy & Society Activities

The aim of the Astronomy & Society Group is to foster Leiden Observatory's mission to engage the Dutch, European and global audiences with the wonders of the Universe and share the scientific, technological, cultural and educational aspects of astronomy with society.

Leiden Observatory - Visitor Centre

The visitors center located in the historic observatory building is open 3 days a week: Wednesdays, Saturdays and Sundays. During regular opening hours we have had 12565 visitors in 2016. The number of private tours that were held in the historic observatory reached an all-time high of 201 tours, serving more than 2800 people in the process.

The visitors center, along with the historic telescopes available in the building, were also opened during several nights in 2016 for special events such as Museumnacht, Midzomernacht, and De Nacht van Kunst & Kennis. These events drew large crowds, about a thousand visitors per night.

The historic building has also maintained a strong presence on social media platform Facebook. The maximum reach of a Facebook post was 6689 people, which is triple the maximum reach of the most popular facebook post in 2015.

In April 2016 we have set up a new committee which is designing a plan to revamp the visitors centre of the old observatory. By means of several meetings with our colleagues from, among others, Boerhaave and Naturalis, a project plan has been created that aims to open the doors of our renewed visitors centre on the 8th of February 2019 (the dies natalis of the University Leiden).

Universe Awareness

2016 was a good year for Universe Awareness: We celebrated our 10 year anniversary with a number of international contests, including the first UNAWE Win Your Own Telescope competition, the European Astronomy Space Art Contest and the first Space Scoop Comic Contest, all of which were very successful.

In 2016, the Universe Awareness international community reached 106219 children, trained 2339 teachers, and offered activities in 3278 schools around the world. The Universe Awareness website was also visited by 106 000 visitors. This means that Universe Awareness has now engaged over 500 000 children around the world.

We also welcomed new national nodes

UNAWE Ukraine, UNAWE Haiti, UNAWE Peru and UNAWE Moldova to our international community. We participated in the Communicating Astronomy with the Public Conference in Colombia and the International Space Education Workshop in Leiden. In 2016, UNAWE was also the educational partner of Asteroid Day, and developed educational resources for children in collaboration with Las Cumbres Observatory Global.

Together with Space Awareness and the Universe Awareness national nodes in South Africa, Morocco, Portugal, Mongolia and Japan also released a short video about our common mission of inspiring every child with the wonderful cosmos.

Space Scoop

Space Scoop, a news service about astronomy for children, published 29 Space Scoops on www.SpaceScoop.org, www.unawe.org and www.space-awareness.org. Space Scoops were published in 23 languages by more than 40 volunteers. To celebrate the new Space Scoop website and Universe Awareness' 10-year anniversary, Space Scoop asked its readers to create their very own Space Scoop Comic in 2016. Anyone between the ages of 8 and 18 years was invited to create an original short comic based on one of the Space Scoop stories from www.spacescoop.org. 30 countries registered to collect entries nationally, and 20 countries submitted their winning entries to the international contest. Judges from 20 countries selected 44 national contest winners aged between 8-18 years. All the comics can be enjoyed on the UNAWE Flickr stream. From the 44 runner-up comics, a panel of judges from the fields of education and science communication have chosen four international winners. The overall winner received a KANO computer, while runners up took home prizes including Galileoscopes and cosmic goodie bags. In addition, the winning artwork was displayed on the international Universe Awareness website and Space Awareness website.

UNAWE Refugee Programme

In the first half of 2016, UNAWE implemented Discovery Club, an after-school Science, Technology, Engineering, Arts and Mathematics (STEAM) programme developed to inspire, educate and entertain children (and parents) in refugee centres. Every Saturday afternoon, children of the Discovery Club came together at the refugee center in Leiden to do educational activities with their parents and local volunteers. Together, they did hands-on activities and learned about science and technology, other cultures, as well as arts and crafts, gaining knowledge and a sense of much-needed normalcy.

Discovery Club held weekly sessions with a group of around 30 children. This volunteer-led initiative in collaboration with the COA (Centraal Orgaan Opvang Azielzoekers) received a great deal of positive feedback from both the inhabitants (children and parents) and staff at the centre: Discovery Club was a great success. In the same period, Universe Awareness also collaborated with ICLON (Leiden University Graduate School of Teaching) in the Mobile Educator project and trained 5 Syrian teachers in science and astronomy education. The work of Universe Awareness in education for refugees was also highlighted by the ECSITE (European Network of Science Centers and Museums) Spokes publication.

In September 2016, UNAWE implemented a series of educational activities at Basisschool De Verrekijker, a primary school for refugee children in Katwijk, the Netherlands. In this month-long astronomy project, more than 180 children and their teachers engaged in astronomy educational activities: participants learned about the planets of our Solar System, created their own spaceships, and much more. This astronomy-themed month was concluded on 30 September with a visit from the NOVA Mobile Planetarium and a family day where parents and siblings could see what the students learned and created.

Space Awareness

In 2016 the Space Awareness project faced its implementation phase with the organization of 80 activities reaching directly 3000 teachers, almost 2000 children and 14000 additional people from general audience in eleven countries. We welcomed three new dissemination nodes that joined the project to represent Austria, Israel, and Turkey, raising the number of national representatives to 24 in 23 countries across Europe, Africa and Asia.

More than 190 educational resources were selected, reviewed, or developed by the project team. Working in close collaboration with ESA, the project developed 20 educational activities for secondary level related to the Copernicus and Galileo Programmes. A successful international space education workshop was organised in October 2016 in Leiden, with the collaboration of the European Space Agency and the Galileo Teacher Training Program. Over 100 professional educators participated in a 5 days' conference that offered presentations and workshops.

The project organized the first Space Awareness Massive Online Open Course (MOOC) focused on Teaching with Space and Astronomy in your Classroom in fall 2016. The MOOC was a big success as over 1,400 teachers enrolled and 369 of them (39% completion rate) completed the course, which is a high completion rate for this type of initiatives. Three more Space Awareness MOOCs will be organized in 2017.

We also organized a summer school course for teachers in Marathon Greece with 21 participating teachers from different countries. A new edition of the summer school will be organized in July 2017.

Efforts were taken to investigate how space scientists influenced their decisions relating to space and technical career choices as well as exploring the attitudes and opinions towards science generally as well as space science in particular from students aged 9-16 from across Europe. The latter study, encompassing 7,500 replies across 11 different countries, is designed to provide the first large-scale investigation of school students' perceptions of space science. The results of the survey will be announced during the third year of the project.

Other activities included synergies with the Universe Awareness programme on both the organization of the Space Scoop Comic contest and the production of the short video about our common mission of inspiring every child with the wonderful cosmos.

Teaching Enquiry With Mysteries Incorporated

2016 marked the final year of the three-year EU-funded TEMI project, concluding the project with several successful initiatives. Over the first part of 2016, the Leiden Observatory TEMI team trained another 50+ Dutch-speaking teachers in the TEMI methodology, over the course of three two-day Teacher Trainings, performed in collaboration with the Scholierenacademie Groningen, Cosmodrome Genk (Belgium) and ICLON Leiden. These intensive trainings used the TEMI methodology to familiarise the participants with Enquiry Based Learning as well as show them methods to capture the curiosity of students in order to engage intrinsic motivation to learn about new concepts. A key part of these trainings was to support the participants in developing their own classroom material, to introduce their students to Enquiry Based Learning.

Together with Europlanet, the Leiden Observatory TEMI team conducted a one-day workshop in Athens during the Summer, this time to introduce scientists with ways to engage with schools and show them ways to execute engaging school activities more effectively. In this workshop, the scientists were introduced with the TEMI 5E model: a framework to naturally incorporate an Enquiry Based approach in public talks and school activities, to activate students to learn more about scientific topics.

In April 2016, Leiden Observatory co-hosted the international TEMI Conference, where more than 200 teachers and educators from all over Europe came together to share with each others what they learned from the TEMI methodology. During this three-day conference many hands on workshops were held to showcase best practices in using the TEMI methodology and to use mysteries to engage the curiosity of learners. This conference marked the conclusion of the successful, innovative and creative European project TEMI.

Social Networking

L.A.D. **"F. Kaiser"**

The Leidsch Astronomisch Dispuut "Frederik Kaiser" is the society for Leiden astronomy students, named after the founder of the historic observatory building in the centre of Leiden. It is part of De Leidsche Flesch, the student association for Physics, Astronomy, Mathematics, and Computer Science. Kaiser strives to promote integration between students and staff at the Leiden Sterrewacht by organising social activities. In addition, Kaiser facilitates practical observing sessions using the historic telescopes of the old observatory, and is active with outreach events.

Social events

Very popular is the annual football tournament, which includes teams from both observatory staff and students. Kaiser also organizes student dinners, movie nights, excursions, and a series of lunch talks for both students and staff - e.g. on topics like tracking espionage satellites or citizen science projects such as Galaxy Zoo. Kaiser also organises observing very succesful events at the Old Observatory with the historic telescopes. This is done by the Observing Committee, who organises as many observing nights as the weather will allow.

Outreach

L.A.D. 'F. Kaiser' trains the students that perform tours through the historic observatory. In order to keep the tours up to date and find new material, Kaiser also has a Historical Committee, who studies the institute achives and inverviews older Astronomers to find more information about the history of the observatory. The tour guides, along with other members, also form the backbone of the organisation of major public events at the observatory, such as the 2016 Mercury Eclipse,the annual Nationale Sterrenkijkdagen (National Stargazing Nights), and the Nacht van Kunst en Kennis (Night of Art and Knowledge). The Kaiser Spring Lecture Committee also organised the third edition of their annual public lecture series, de Kaiser Lente Lezingen, also at the Old Observatory. The lectures were given by Ewine van Dishoeck, Mike Garret, Frans Snik and Rob van Gent, and over 300 tickets were sold. The Committee consisted of Olivier Burggraaff (president), Brecht Simon (treasurer), Joey Braspenning (assessor PR) and Kimberly Emig (assessor Speakers).

The 2015/16 Kaiser board consisted of Mark Knigge (chairman), Dennis Vaendel (treasurer/secretary), Dominique Petit dit de la Roche (assesor Old Observatory) and Kimberly Emig (assessor Outreach). The 2016/17 board consists of Olivier Burggraaff (chairman/treasurer), Joey Braspenning (secretary), Lennart van Sluijs (assessor Old Observatory) and Cameron Mackie (assessor Outreach).

VO-S, the Leiden Observatory **Alumni Association**

Studying or working at Leiden Observatory is an unforgettable experience to many, with on the one hand the exciting discoveries in astronomy, and on the other the strong social aspects - fuelled by the early participation of students in astronomical research and the lively social interaction in this relatively small, international community. It comes to no surprise that when (post-)graduates or staff leave Leiden Observatory for pursuing a career elsewhere, good memories often remain of this special period in life. The Vereniging van Oud-Sterrewachters (VO-S), the Leiden Observatory alumni association, helps in bringing alumni together and keeping these ties alive, both on the social level as well as feeding the general interest in scientific research. As such it serves as a 'platform' or network between alumni and the institute. Activities comprise of the both social and science-related events. The association presently has nearly 150 members, with membership open to all Leiden Observatory alumni and staff.

Social events

2016 has been yet another year with a variety of activities for alumni organised by our association, in good cooperation with the Leiden Observatory. In April, prior to the Oort Lecture by Prof. Joe Silk on the 'Limits of Cosmology', VO-S organised the traditional social gathering in a local pub. And in early July, some 20 alumni convened in front of the Oort building to join the annual Observatory barbeque event in and enjoyed this great opportunity to renew ties with Observatory students and staff.

A definite highlight was our annual meeting held at Dwingeloo, celebrating the 60th anniversary of the 25m radio telescope. Some 35 alumni met at the center of the old village, where they enjoyed a delicious lunch buffet. Later, the general assembly meeting was held at the Astron/JIVE building. Our guest speaker was dr. Astrid Elbers, who took us back in time and shared her insights on the success of early radio astronomy in the Netherlands, including the central role of Jan Oort. Shortly after we were shown around in the famous 25m radio telescope by the CAMRAS foundation, a group of volunteers - amongst which Leiden alumni - that has restored the instrument to its full glory in the past years.

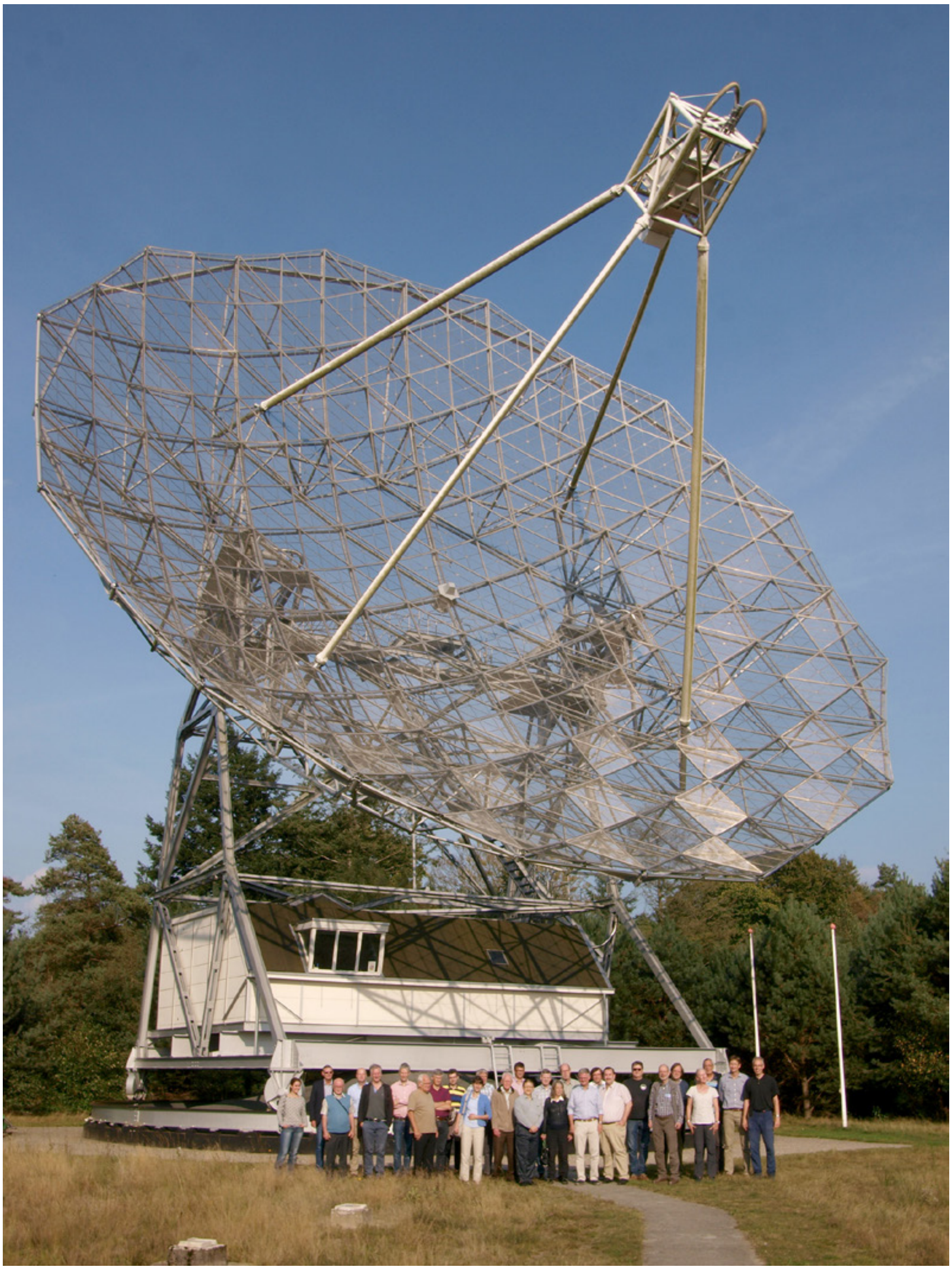
Other activities

One of the new activities of VO-S is to share career experience outside astronomy with students and post-graduates. Two talks were held by alumna Leonie Snijders for bachelor and master students. Further some individual coaching sessions took place, upon request by individual students.

Communication with our members on astronomic highlights and our upcoming activities took place via the website, newsletters and e-maill. We thank the MarCom team of the Faculty of Science for their ongoing efforts in updating our website and preparing our newsletters twice a year.

Join the VO-S

For contact and membership of our alumni association: visit our website at www.vo-s.nl or send an email to: vo-s@strw.leidenuniv.nl



Annual meeting at Dwingeloo / courtesy A. Elbers

Organization

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Full professors

Prof.dr. B.R. Brandl
Prof.dr. E.F. van Dishoeck
Prof.dr. M. Franx
Prof.dr. C.U. Keller
Prof.dr. K.H. Kuijken
Prof.dr. H.V.J. Linnartz
Prof.dr. F.H. van Lunteren
Prof.dr. S.F. Portegies Zwart
Prof.dr. H.J.A. Röttgering
Prof.dr. J. Schaye
Prof.dr. I.A.G. Snellen
Prof.dr. A.G.G.M. Tielens
Prof.dr. P.P. v.d. Werf
Prof.dr. P.T. de Zeeuw

Professors by **Special Appointment**

Prof.dr. D. van Delf
(Stichting tot beheer Museum boerhaave, Directeur Museum Boerhaave)

Prof.dr. N.J. Doelman
(J.H. Oortfonds, TNO)

Prof.dr. P. Ehrenfreund
(CEO, German Aerospace Center)

Prof.dr. M. Fridlund
(J.H. Oortfonds, staff scientist ESTEC/ESA)

Prof.dr. M.A. Garrett
(Jodrell Bank Centre for Astrophysics)

Prof.dr. J.S. Kaastra
(Senior scientist SRON)

Prof.dr. H.J. van Langevelde
(Director JIVE Dwingeloo)

Associate and **Assistant** Professors, **Senior** Researchers

Dr. R.J. Bouwens
Dr. J. Brinchmann
Dr. A.G.A. Brown
Dr. J.A. Hodge
Dr. H. Hoekstra
Dr. M.R. Hogerheijde
Dr. M.A. Kenworthy
Dr. I.F.L. Labbé
Dr. A. Patruno
Dr. E.M. Rossi
Dr. P.M. Rodrigues Dos Santos Russo
Dr.ir. F. Snik
Dr. R. Stuik
Dr. R.P.J. Tilanus

Emeriti

Dr. A.M. van Genderen
Prof.dr. H.J. Habing
Prof.dr. V. Icke
Prof.dr. F.P. Israel
Prof.dr. W.J. Jaffe
Dr. J. Lub
Prof.dr. G.K. Miley
Drs. R.S. le Poole

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Dr. J. Bedorf
Dr. M.A. Bilicki
Dr. J. Bouwman
Dr. H. Buddelmeijer
Dr. M. Cacciato
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Dr. V.D.F. Taquet

Dr. C.R. D'Angelo

Drs. D.J. Klaassen

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Brinchmann

- Secretary/treasurer, Leids Kerkhoven-Bosscha Fonds
- Secretary/treasurer, Leids Sterrewacht Fonds
- Secretary/treasurer, Jan Hendrik Oort Fonds
- Member, Leids Universiteits Fonds International Study Fund

Brown

- Member, Faculteitsraad

Van Dishoeck

- Coordinator, Fundamentals of Science profile area Leiden University

Franx

- Director, Leids Kerkhoven Bossche Fonds
- Chair, board of directors, Leids Sterrewacht Fonds
- Chair, board of directors, Oort Fonds

Israel

- Member, mid-term review-commissie onderwijs Natuur- en Sterrenkunde
- Vice-chair, Editorial Board `Mare'

Kuijken

- Member of Leiden Latin America/Caribian Committee
- Member of Leiden University delegation to Brazil, March 2016

Linnartz

- Member FMD/ELD user committee
- Member WN committee OC chairmen

Lub

- Member, Faculty Library Committee

Röttgering

- Member, board of directors of the faculty of Science
- Member, Leiden university wide committee on policies related to top-researcher

Schaye

- Member, WeCo (Permanent Committee for Academic Practice)

Snellen

- Member, student travel fund of Leiden University Fund (LISF)

vd Werf

- Organist Academy Auditorium
- Member, Task Force Strenghtening Master Programmes

Science policy functions

Bouwens

- Dutch time allocation panel for the telescopes on La Palma
- Deputy coordinator Euclid Science Ground Segment, OU-NIR

Brandl

- PI, METIS (mid-IR instrument for the E-ELT)
- Deputy co-PI MIRI (mid-IR instrument for the JWST)
- Member, Review committee, BMBF Verbundforschung
- Member, Evaluation Board, Leibniz Gesellschaft
- Member, NOVA Instrument Steering Committee (ISC)
- Member, ESO Contactcommissie
- Chair, SOC, "Science Enabled by Novel Infrared Instrumentation"

Brinchmann

- Legacy Science Coordinator, Euclid mission
- Galaxy and AGN evolution science working group coordinator, Euclid mission
- Member, Diversity committee, Euclid mission
- Member, Euclid Editorial Board
- Member, Euclid Calibration Working Group, Euclid Archive User Group
- Member, MUSE Science team
- Coordinator, MUSE data management
- Member, JWST Data Processing Working Group

Brown

- Chair, Gaia Data Processing and Analysis Consortium
- Member, Gaia Science Team
- PI Gaia/Netherlands
- President, IAU Commission A1
- Member, Steering Committee IAU Division A
- Associate Member, International Earth Rotation and Reference Systems Service
- Member, Executive Board GENIUS FP7-Space Collaborative Project

van Dishoeck

- Scientific Director, Netherlands Research School for Astronomy (NOVA)
- President-elect, International Astronomical Union (IAU)
- Co-Editor, Annual Reviews of Astronomy & Astrophysics
- Member, Gebiedsbestuur Exacte Wetenschappen (GB-E)
- Member, National Committee on Astronomy (NCA)
- Chair, A-ERC PE9 panel
- Co-PI, European JWST-MIRI consortium
- Member, steering commitee NCCR PlanetS Switzerland

Franx

- Member, KNAW
- Member, Nova Research Committee
- Member, NWO M exacte wetenschappen commissie
- Member, NIRSPEC Instrument Science Team
- Member, 3DHST team
- Member, Lega-C team
- co-PI, Ultravista Survey
- Member, MUSE Science Team

Fridlund

- Member CHEOPS Science Team representing ESA

Hodge

- Member, SOC Lorentz Workshop 'Physical characteristics of normal galaxies at z>2'
- Member, Next Generation Very Large Array (ngVLA) High-redshift Universe working group
- Member, Origins Space telescope Galaxy Evolution Science Working Group
- Chair, licentiate seminar of Judit Fogasy, Chalmers Observatory
- Member, SOC Oort Workshop 'Feedback in galaxy formation'

Hoekstra

- Deputy coordinator NOVA network 1
- Member NWO Vidi grant selection committee
- Vice-chair ESO Observing Program Commitee
- Member Lorentz Center Astronomy Advisory Board
- Chair SOC "A century of gravitational lensing", Leiden, July 11-15
- Member Euclid Consortium Coordination Group
- Member Euclid Consortium Editorial Board
- Euclid Cosmology Science Coordinator
- Member Athena Mission

Hogerheijde

- Program director, Netherlands node ALMA Regional Center
- Member, MATISSE Science Group
- Member, European Science Team Origins Space Telescope
- Member, Board of Directors Leids Kerhoven-Bosscha, Oort, and LeidsSterrewacht Foundations
- Member, ALMA Regional Center Coordinating Committee
- Member, German SOFIA Time Allocation Committee
- Member, Scientific Organizing Committee, Half a Decade of ALMA: Cosmic Dawns Revealed (Indian Wells, CA, USA, 20-23 September 2016)
- Member of the Project Science Team, European Extremely Large Telescope, ESO
- Member of the Board, Isaac Newton Group of Telescopes, Canary Islands, Spain

Icke

- Member of the Advisory Board of the Institute for Interdisciplinary Studies (University of Amsterdam)
- Member of the Board of Regents of the Gerrit Rietveld Academie (Amsterdam)
- Member of the Advisory Board of CAMRAS (Dwingeloo)
- Member of the Board of Editors of the Nederlands Tijdschrift voor Natuurkunde
- Member of the Jury, Huibregtsenprijs (KNAW)
- Member of the Advisory Council, Stichting Beelden In Leiden

Israel

- Chair, NWO Top-1 Panel
- Chair, Skepsis Foundation

Jaffe

- Chair:Veni Selection Committee
- MATISSE Project Scientist
- Dutch Member:European Interferometry Initiative
- IAU FITS working group
- Various IAU scientific committees

Kaastra

- Principal Investigator XMM-Newton Reflection Grating Spectrometer (ESA)
- Principal Investigator, Chandra Low Energy Transmission Grating Spectrometer (NASA)
- Member, Hitomi Science Advisory Committee (On behalf of ESA

Keller

- Member Editorial Advisory Board of Europhysics News
- Member of the NWO VIDI grant selection committee
- Member of the EPA Network Task Group on Citizen Science, European Environmental Agency, Copenhagen, Denmark

Kenworthy

- China FWN Committee
- High Contrast Imaging manager for METIS
- High Contrast Imaging lead for ERIS (VLT thermal infrared imager)
- NASA and NSF Reviewer

Kuijken

- Scientific Delegate from the Netherlands, ESO Council
- Chair, ESO contact committee
- Member and Vice-chair, Netherlands Committee for Astronomy
- Board member, SRON
- Member, steering committee National Science Agenda, Route “Building Blocks of Space, time and matter”
- Lead, Euclid Consirtium “Complimentary Observations Group”
- Member, Search committee, NWO chair of Natural Sciences board
- Principal Investigator, ESO KiDS Survey
- Principal Investigator, OmegaCAM project
- Co-investigator, ESO VIKING Public Survey
- Co-investigator, Planetary Nebulae Spectrograph project
- Board Member, Physics Society Diligentia (the Hague)
- Board Member, Kapteyn Fonds (Groningen)

van Langevelde

- Member consortium board of directors European VLBI Network
- Member RadioNet consortium board
- Coordinator of the JUMPING JIVE project
- Member of the ASTERICS consortium board
- Member of the AENEAS consortium board
- Member of the Dutch URSI committee
- Chairman board of directors Leids Kerkhoven Bosscha Fonds
- Member board of directors Leids Sterrewacht Fonds
- Member board of directors Jan Hendrik Oort Fonds
- Member SKA klankbordgroep NL
- Member of the ALMA Scientific Advisory Committee (ASAC)
- Member of the ALMA European Scientific Advisory Committee (ESAC)
- Member of the SKA Science Working Group “Cradle of Life”
- Member of the SKA Science Working Group “The Galaxy”
- Member of the SKA Science Working Group “Cradle of Life”

- Member of the SKA Science Focus Group on VLBI
- Chair of the SKA Consortium Board for Signal and Data Transport (SaDT)

Linnartz

- Board member IAU subdivision Laboratory Astrophysics
- Vice chair division XII / IAU commission 14 / working group solids and their surfaces
- Editorial board member 'Journal of Molecular Spectroscopy'
- Member SOC of international ‘Molecular High Resolution

Spectroscopy Symposium’

- Member SOC 'ECLA2016' (European Conference on Laboratory Astrophysics)
- Member SOC 'IR Plasma Spectroscopy Meetings'
- Member SOC astrochemistry within CHAINS
- Chair Lorentz Center workshop 'SWEDIBLES'
- Chair Lorentz Center workshop 'ICE AGE - the era of JWST'
- Solid state astrochemistry theme coordinator within the Dutch
- Astrochemistry Network (DAN)
- Biomarker theme coordinator within the Planetary and Exo Planetary
- Science Network (PEPSCI)
- Workgroup leader within the H2020 ITN EUROPAH
- Workgroup leader, FOM group FOM-L-027
- Group leader within Holland Research School for Molecular Chemistry

Lub

- Treasurer, Dutch Astronomical Society (NAC)
- Chairman, Astronomy & Astrophysics Board

Miley

- Trustee, Associated Universities Inc. (AUI- managing body of US National
- Radio Astronomy Observatory)
- Member, Board of Governors of the LOFAR Foundation
- Member, South African Astronomy Advisory Committee
- Member, Advisory Committee, School of Cosmic Physics, Dublin Institute for Advanced Studies
- Chair, LOFAR Survey Science Group, Highest Redshift Objects
- Member, ERC Synergy Proposals Panel

Portegies Zwart

- Editor of Springer Journal of Computational Astrophysics and Cosmology
- President of the IAU commission C.B1 Computational Astrophysics
- PRACE, member of the Scientific Steering Committee
- Lorentz Center, Computational Science board member
- Qatar NSF, Qatar national science foundation, external advisor
- IAU Member of Division VII Galactic System
- IAU Member of Division VII Commission 37 Star Clusters \& Associations
- NOVA ISC, AMUSE progress representative
- Lorentz Center, Advisory board computational science
- VPRO Noorderlicht, science advisory board
- European Ambassador, Meta Institute for Computational Astrophysics,
- Beta Ambassador for the Netherlands

Rossi

- PI, LOFAR surveys: Opening up a new window on the Universe
- Member, Science Advisory Committee ASTRON
- Member, Board LOFAR International Telescope
- Member, Netherlands Committee for Astronomy
- Chair, Board of the Netherlands Research School for Astronomy
- Member, SKA Science working group on radio continuum surveys
- Member, NL-SKA contact committee
- Member, Board Holland Space Cluster
- Member, advisory board Delft University Space Institute
- Chair, Euclid (ESA's dark energy satellite mission) consortium board
- Member, Leiden university wide committee on policies related to top-researchers

Schaye

- PI, MUSE QuBES (Quasar Blind Emitter Survey)
- PI, EAGLE collaboration (Evolution and Assembly of GaLaxies and their Environments)
- Member of the steering committee, Virgo Consortium for cosmological supercomputer simulations
- Member of the executive board, MUSE (Multi Unit Spectroscopic Explorer)
- Builder, MUSE GTO team
- Core member, LOFAR Epoch of Reionization science team
- Member, Athena X-IFU science team
- Member, EUCLID cosmological simulations working group
- Member, WEAVE QSO science team
- Scientific Editor, Monthly Notices of the Royal Astronomical Society
- Scientific Editor, Scientific Reports
- Member of the board, "Stichting Studiefonds J.C. Kapteyn"
- Member of the board, Pastoor Schmeits prize

- Member, Scientific Organizing Committee, "The challenges of upcoming HI surveys", Dwingeloo
- Chair, Local Organizing Committee, ``Computational cosmology''
- Member, SOC, "Frontiers of astrophysical modeling''
- Member, SOC, "A Decade of the Star-Forming Main Sequence''
- Member, SOC, "What matter(s) around galaxies''
- Member, SOC, "Deconstructing Galaxies at Cosmic Noon: The present and future of deep spectroscopic surveys at high redshift''
- Member, SOC, "Feedback in galaxy formation''
- Member, SOC, "Computational cosmology''

Oonk
- SKA Our Galaxy science working group
- SKA Extragalactic spectral line working group
- LOFAR Calibration and Imaging Tigerteam (advisor)
- LOFAR Galactic Working Group
- LOFAR Users Committee
- Leiden LOFAR – SURFSARA LTA e-infra group (chair)
- Herschel Data Products User Group (chair PACS spectroscopy)
- Reading committees: L.K. Morabito (Leiden, 2016)

Snellen
- Panel Chair, ESO Observation Program Committee (OPC)
- PI, Multi-site All-Sky CAmeRA (MASCARA)
- Dutch Co-PI, HARPS3 at the INT
- EU FP7 Network progress reviewer
- EU ERC grant proposal referee
- Member, board of Dutch Astronomy Society (NAC)
- Member, METIS Science Team
- Member, PLATO consortium
- Member, HIRES/E-ELT consortium
- Member, NWA, Route 4 committee
- Member of Editorial Board, Zenit

Snik
- Member NOVA Instrument Steering Committee
- Member Isaac Newton Group of Telescopes Time Allocation Committee
- Editor Nederlands Tijdschrift voor Natuurkunde

Tielens
- Chair of the Science Advisory Committee SRON
- Editor in Chief, Molecular Astrophysics
- Editor in Chief, AstroPAH

v.d. Werf
- Principal Investigator, JCMT Cosmology Legacy Survey
- Principal Investigator, DESHIMA spectrograph
- Co-investigator, MIRI
- Project Scientist, AMKID Submm camera
- Member, STFC Herschel Oversight Committee
- Member, METIS Science Team
- Member, Herschel Astrophysical Terahertz Large Area Survey consortium
- Member, ALMA-LABOCA ECFS Survey consortium
- Member, ALMA Spectroscopic Survey consortium

Grants

P.I.	Funder	Proposal Title	Grant
Kenworthy	NWO-FAPESP	Adaptive Optics development for Extremely Large Telescopes	294 k€
Hoekstra	NWO VICI	Turning galaxy alignments into cosmological weighing scales	1500 k€
Portegies Zwart	NWO-M	Little Green Machine-II: A high performance parallel multipurpose supercomputer for big data production and processing	264 k€
Kuijken	NWO-Groot	Dutch Science Data Centre for the Euclid Mission	387 k€
Hodge	NWO-VIDI	Shedding New Light on Star Formation in the Early Universe	800 k€
Hacar Gonzalez	NWO-VENI	ORION-4D: Towards a unified theory of low- end high-mass star formation	250 k€
Bouwens	NWO- TOP1	The Growth of Baby Galaxies in the Early Universe, as seen by Multi-wavelength views of unprecedented sensitivity	663 k€
Linnartz	Astrochemie DAN II	Molucular Complexity in Insterstellar Ices	214 k€
Hogerheijde	Astrochemie DAN II	Circumstellar ice and snow lines - Photochemistry at the edge	171 k€
Tielens	Astrochemie DAN II	Photo-processing, reactivity and spectroscopic characteristics of large PAHs and their derivatives	119 k€
Gunnawardhana	IEF	Investigating evidence of high-mass variations of the stellar initial mass function	166 k€
Snellen	EU Advanced ERC	Exoplanet atmospheres as indicators of life: From hot gas giants to Earth-like planets	2.301 k€
Linnartz /Tielens	MSCA-ITN	The Extensive and Ubiquitous Role of Polycyclic Aromatic Hydrocarbons (PAHs) in Space	681 k€
Russo	H2020 SWAFS	Enhancing the Responsible and Sustainable Expansion of the Science Shops Ecosystem in Europe	118 k€

ANNUAL REPORT /16

Research Institute Leiden Observatory

Onderzoekinstituut Sterrewacht Leiden

Sterrewacht Leiden

Universiteit Leiden
The Netherlands