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ANNUAL REPORT

Research Institute Leiden Observatory

Onderzoekinstituut Sterrewacht Leiden

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Sterrewacht Leiden

Universiteit Leiden
The Netherlands

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Foreword

Dear **reader**,

I am very proud to present to you the new-style Annual Report of Leiden Observatory for the year 2015. In a break with tradition, we completely overhauled the format with respect to previous years. With this new set up we hope to more clearly communicate the exciting work that we are doing at our research institute, the complex challenges we try to tackle, and convey some of the enjoyment we have while doing this – all in a layout that is more reader friendly.

New features of this report are a general introduction to the Observatory and its people, and a Calendar of Events, which gives a quick overview of all the important happenings throughout 2015. In the research highlight section, instead of giving a 'complete' overview several of our staff members write about their research. For example, Joop Schaye, who this year won a prestigious NWO VICI award, writes about simulating the formation and evolution of galaxies, and Ewine van Dishoeck summarizes exciting new ALMA results.

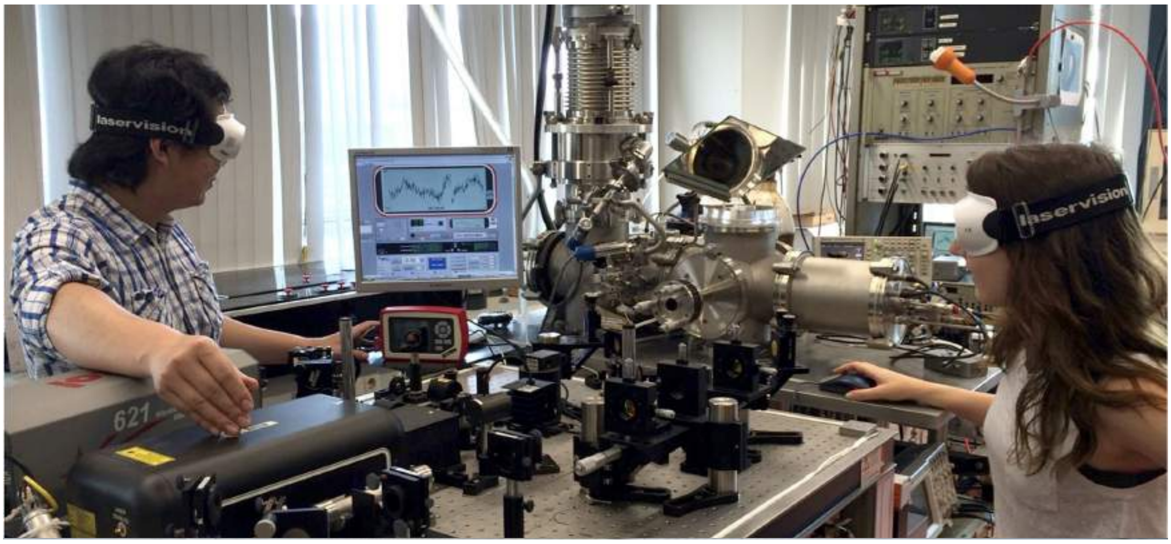
We also made room to discuss other important aspects of our work at Leiden Observatory – e.g. our role in instrument development. Frans Snik, who won a Starters Grant from the European Research Council this year, and Matthew Kenworthy write about new smart ways to search for faint planets orbiting bright stars. This is enabled using liquid crystals in coronagraphs reaching extremely high image contrasts. Jarle Brinchmann shows some of the fantastic first results from the new Multi Unit Spectroscopic Exoplorer (MUSE) on the Very Large Telescope of the European Southern Observatory – which was built by a consortium in which the Netherlands Research School for Astronomy (NOVA) played an important role.

In the new format we also highlight the different aspects of our education. We explain the setup and goals of our Bachelor and Master in Astronomy studies. The number of students that follow our programs have increased dramatically over recent years. Another important strand of what we do at Leiden Observatory is our Outreach and Popularisation program. This report gives a nice overview of the wide range of activities that we do to inform the general public of the wonders of the Universe. At the end you can still find general information about our organisation, e.g. the names of all our staff members, postdoctoral fellows and PhD students, committee memberships and science policy functions.

I hope you like our new Annual Report as much as I do, and please, do let us know your comments!

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 der Hulst. Currently, Leiden Observatory is proud to be one of the largest and top astronomical research institutes in Europe. It has 20 scientific staff members, about 60 postdoctoral researchers, 75 PhD students, and 150 undergraduates. Among its professors are three Dutch Spinoza Prize winners. Prof. Tim de Zeeuw is currently 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 are 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 principle 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 100 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 used to launch a career in business or industry.

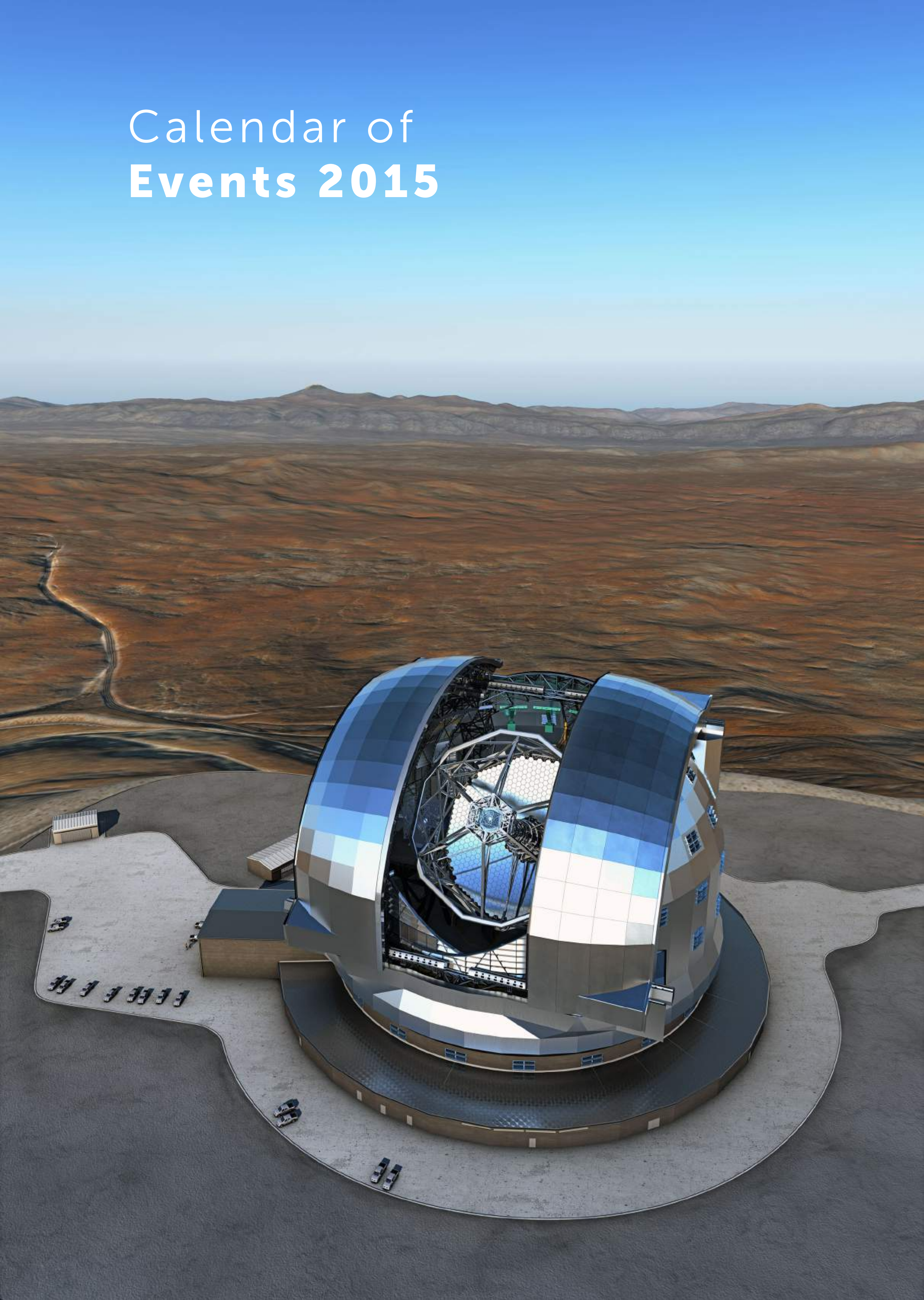
In collaboration with ESTEC in Noordwijk, Leiden Observatory organises every year the Leiden/ESA Astrophysics Program for Summer Students (LEAPS), in which talented students from all over the world conduct a summer research program at the Observatory.

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.F. Kaiser conducts over one hundred guided tours a year of the antique telescopes.

Leiden Observatory also hosts the international office of the Universe Awareness programme, UNAWE, use 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 2015**



January

- **[14-18]** Story of Light Festival in India. India's first science-meets-art festival, being conducted in Panaji, Goa. The Festival is a brainchild of Jaya Ramchandani, alumnus of the Master Programme Astronomy & Science Based Business.
- **[26]** Start of crowd funding for the solar telescope at the historic observatory building. A unique collaboration between volunteers, astronomers, instrument builders, and the public.
- **[26]** Enormous ring system discovered around exoplanet J1407b by astronomers from Leiden and the University of Rochester (USA)

February

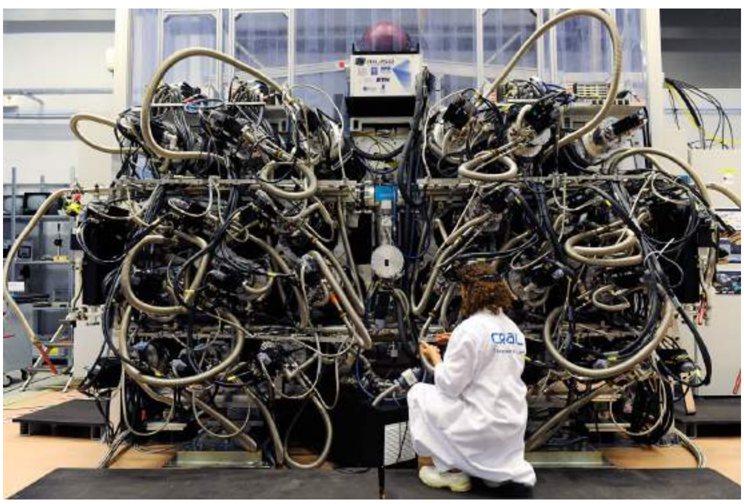
- **[13]** Prof. Joop Schaye receives a prestigious NWO VICI grant of 1.5 million Euro to expand his research group.
- **[18]** Crowd Funding for solar telescope is a great success, with 180 donations worth 20 thousand Euro.
- **[24]** New supercomputer at Leiden Observatory processes LOFAR data at high speed. The data are expected to provide new insights in the formation of galaxy clusters and quasars.
- **[24]** The new MUSE instrument at ESO's Very Large Telescope now surpasses the Hubble Space Telescope in making the best three-dimensional representation of the distant universe.

March

- **[3]** Secretary of state Sander Dekker reveals a plaque at the Academy Building commemorating the first ESO summit.
- **[12]** Nienke van der Marel is one of the new faces on the new KNAW website 'the Faces of Science', introducing young scientists.
- **[20]** Cloudy solar eclipse is still popular at the old observatory, with Felix Bettonvil giving a public talk about solar telescopes.
- **[26]** Prof. Ewine van Dishoeck receives the Lodewijk Woltjer Lecture Award 2015.
- **[30]** Leiden astronomer Ingrid van Houten passes away at an age of 93.

April

- **[4]** Using the European VLBI network run from JIVE Dwingeloo Huib Jan van Langevelde and collaborators witness the early development of a young massive star.
- **[7]** The Leiden Master in Astronomy scores high in the 'Keuzegids Masters 2015', and is valued best together with the Astronomy Master at Radboud University.
- **[9]** For the first time complex organic molecules are discovered in an infant star system using ALMA.
- **[23]** Oort Lecture by Prof. Carlos Frenk entitled 'Cosmic origins: everything from nothing'.
- **[24]** An international team led by Andra Stroe and David Sobral discover that old 'dead' galaxies can come back to life through a cosmic tsunami.



May

- **[5]** Astronomers, including Rychard Bouwens, Marijn Frank and Ivo Labbé discover the most distant galaxy ever.
- **[22]** UNAWE wins Scientix Award for 'Universe in a Box' project.

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.

July

- **[1]** Konrad Kuijken is awarded the Humboldt Research Award.
- **[2]** A research team including Matthew Kenworthy see for the first time a young planet grow up using the new vAPP.
- **[9]** The KIDS survey papers are published, mapping the distribution of dark matter.
- **[17]** NWO VENI grants are awarded, to Cassandra Candian and Francesco de Gasperin.
- **[24]** Simon Portegies Zwart is the driving force behind the Computer Diplomacy Challenge during the 18th Computer Olympiad held in Leiden.
- **[31]** Bram Ochsendorf shows with his PhD research that supernovae inflate the Orion giant bubble.

August

- **[5]** Astronomers again destroy the record for the most distant galaxy – at z=8.68.
- **[13]** The very successful LEAPS summer student program comes to a close.
- **[15]** Ewine van Dishoeck becomes the new president-elect of the International Astronomical Union.
- **[27]** Ignas Snellen delivers the Michael West Lecture at Queens University Belfast.
- **[29]** Naomi Greenberg passed away at the age of 92. She was married to the late Mayo Greenberg, Professor of Laboratory Astrophysics in Leiden.

September

- **[9]** Leiden Observatory Science Day
- **[14]** Michael Garrett argues using radio observations of galaxies that very advanced civilizations may not exist.
- **[21]** The Leiden Observatory Heliostat is officially opened.
- **[22]** The exposition of Roland Schimmel is opened in the Old Observatory visitor centre.
- **[28]** The contract for METIS a first light instrument for the European Extremely Large Telescope, is signed.

October

- **[14]** Educators, teachers, and astronomers from 23 countries are present at a UNAWE workshop.
- **[19]** TV program ‘Heel Nederland Kijkt Sterren’ is broadcast from the historic observatory building.
- **[25]** Open Day for the public in the historic observatory building.
- **[28]** Surprising find of molecular oxygen in the Rosetta comet, as shown by a research team including Catherine Walsh and Ewine van Dishoeck.

November

- **[4]** Prestigious ERC Starting Grant awarded to Frans Snik for technology development to probe exoplanet atmospheres.
- **[13]** Team including Leiden astronomers show that PAHs have a much more complex spectral signature than previously thought.
- **[17]** South African - Dutch SKA Data Science Partnership is signed by Mark Garrett in the presence of Dutch Prime Minister Mark Rutte.
- **[25]** Simon Portegies Zwart and Ed van de Heuvel (UvA) explain the mass-loss of the supergiant star Eta Carina as being due to a cosmic double collision.

December

- **[1]** Sebastiaan Haffert wins De Zeeuw – Van Dishoeck Afstudeerprijs for his master thesis.
- **[1]** Prof. Edwin Bergin delivers the Sackler Lecture 2015 entitled ‘Probing the beginnings of planetary birth in the age of ALMA’.
- **[6]** Ewine van Dishoeck delivers the Robert Wilson Lecture at University College London.
- **[6]** For the first time magnetic fields detected near the massive black hole in the centre of our Milky Way using the Event Horizon Telescope.
- **[8]** Astronomers, including Arnout van Genderen, explain a 40-year old blue-violet luminescence around a giant star as due to interstellar molecules.
- **[16]** Astronomers, including Nienke van der Marel, use ALMA to find that massive planets have recently formed in the discs around four young stars.
- **[16]** Launch of Space Scoop, a new astronomy news website for children in 22 languages.
- **[17]** Sterrewacht Christmas Lunch

Agreement signed for METIS instrument for the E-ELT.

Research Highlights

Simulating the **formation** and **evolution** of **galaxies**

Joop Schaye

NWO VICI grant winner 2015

While the haloes of dark matter that are thought to host galaxies can be simulated accurately almost from first principles, this is not the case for the galaxies themselves, which consist mostly of baryonic (i.e. ordinary) matter. The difficulties stem from three problems. First, not only gravity, but also gas pressure and radiative processes are important. Second, a large range of scales needs to be taken into account, from the molecular clouds in which stars are formed to the large-scale structures in which the galaxies are embedded. Third, the different scales are coupled through various feedback processes.

Even with today's most powerful computers, we are still far from able to self-consistently simulate the interstellar medium in a cosmological simulation, i.e. in a simulation of a representative volume. It is thus necessary to make use of "subgrid" modules to model unresolved physical processes, such as the formation of molecular clouds, winds driven by dying stars and supernova explosions, and the growth of black holes. Ideally, such modules use a minimal number of free parameters that can be calibrated using observations to give the quantity of interest at the resolution limit, e.g. the star formation rate as a function of the mean gas density.

For many years the agreement between hydrodynamical simulations and observations of galaxies was poor. Most simulations produced galaxy mass functions with the wrong shape and normalisation, the galaxies were too massive and too compact, and the stars formed too early. Star formation in high-mass galaxies was not quenched and the models could not simultaneously reproduce the stellar masses and the thermodynamic properties of the hot gas in clusters of galaxies.

However, in recent years the agreement between simulations and observations has improved markedly. Cosmological simulations can now match many properties of the intergalactic medium, and simulations zooming in on individual objects produce disc galaxies with realistic sizes and masses. However, until very recently, a cosmological simulation that reproduces the observed distribution of the most basic properties of galaxies, such as their masses, sizes, and ages, did not exist. This changed with the completion of the EAGLE (Evolution and Assembly of GaLaxies and their Environments) simulations.

EAGLE is a project of the Virgo consortium for cosmological supercomputer simulations led by Joop Schaye from Leiden and developed in collaboration with researchers from Leiden, Durham (UK), IAC Tenerife (Spain), and Liverpool John Moores (UK). The simulations took several months to run at the "Cosmology Machine" in Durham and at "Curie" in Paris, which are among the largest computers used for scientific research in the U.K. and France, respectively. The largest simulation follows the evolution of a (100 co-moving Mpc^3) cubic volume from the Big Bang to today using 7 billion resolution elements.

Compared to earlier, less successful simulations, the galaxies formed in EAGLE are a closer reflection of real galaxies thanks to the strong galactic winds. Winds powered by young stars and supernova explosions blow away the gas supply needed for the formation of stars. EAGLE's galaxies are lighter because fewer stars form, and they are younger because the stars form later. In the most massive galaxies star formation is quenched altogether because winds driven by accreting supermassive black holes keep the intergalactic gas away from the galaxies.

Because predicting the strength of galactic winds from first principles would require much higher resolution than is feasible, the initial phase of the winds is determined by subgrid models that were calibrated to obtain agreement with the observed present-day galaxy mass function and galaxy sizes. One of the first surprising outcomes of EAGLE was the finding that simulations that match these two observables also broadly reproduce a multitude of other observations that were not considered during the calibration. This includes the evolution of galaxy masses, sizes, star formation rates, gas content, as well as the structure of the gas surrounding the galaxies. This suggests that, contrary to what many researchers thought, no changes to the standard cosmological model or the nature of dark matter are required to match current observations of galaxies.

Having developed a simulation that produces populations of galaxies with characteristics similar to observed galaxies, the EAGLE team has begun to study the evolution of the simulated galaxies and the intergalactic medium in detail. In addition, several groups are using virtual observations of the EAGLE universe to guide the interpretation and design of observational campaigns. EAGLE has also spun off several other simulation projects that re-simulate individual objects with higher resolution or using different physical assumptions.

Although the relatively good agreement between EAGLE and the observations is encouraging, EAGLE does not attempt to model many of the physical processes that are likely important for the formation and evolution of galaxies. For example, EAGLE does not include a cold interstellar gas phase, radiation transport, or magnetohydrodynamics, and EAGLE does not distinguish between different forms of feedback from star formation and between different types of feedback from accreting black holes. At present there are good reasons for such omissions, but many of those arguments would no longer apply if the numerical resolution were increased by a large factor. Ultimately, simulations should be able to predict the efficiencies of the most important feedback processes and hence to predict, rather than calibrate to, the galaxy stellar mass function.

The EAGLE team is already preparing the next generation of cosmological hydrodynamical simulations, which will model the onset of a cold ($T << 10^4$ K) interstellar gas phase. This is expected to resolve some of the discrepancies with observations that have come to light, principally the fact that EAGLE galaxy discs are not as thin as observed, and it will enable a more physical treatment of star formation and galactic winds.

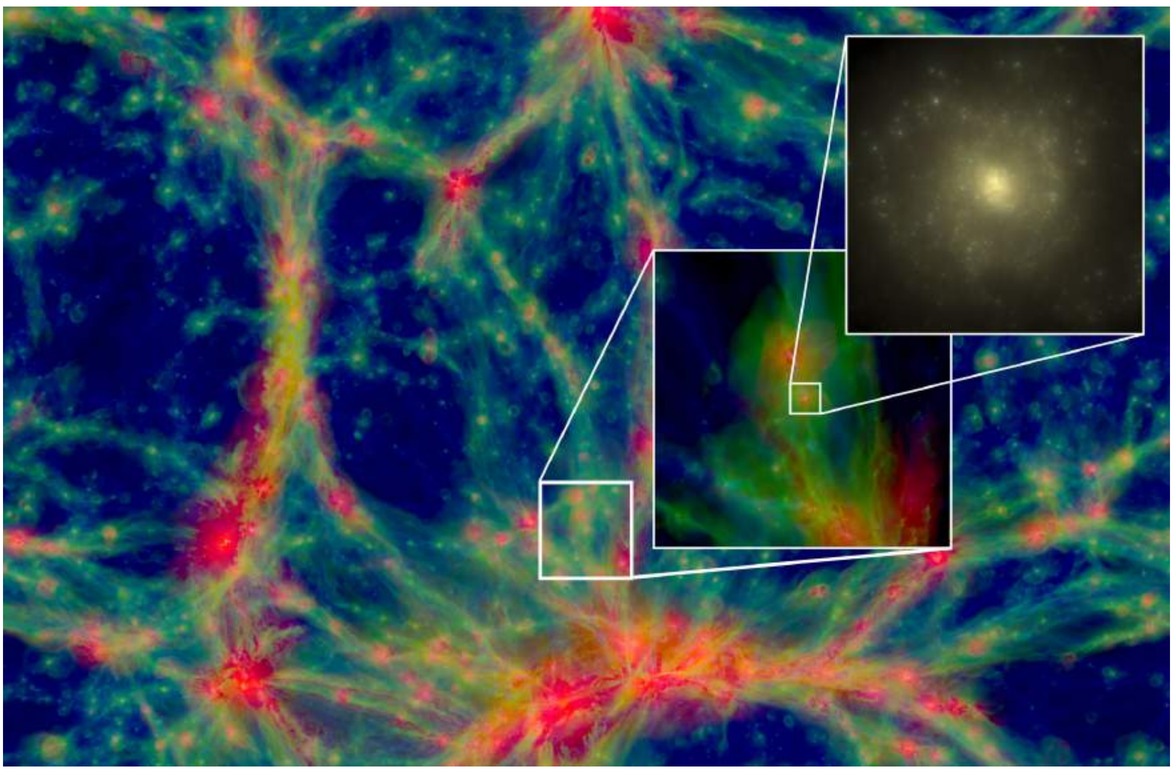


Fig.1: The EAGLE simulation.

Explosive **growth** of **galaxies** in the very **early universe**

Ivo Labbé

Understanding when and how the galaxies formed and evolved from the first dark matter seeds into the diverse population of spiral and elliptical galaxies in the present day universe is one of the most exciting and challenging topics of modern astronomical research. Research into the early universe has shifted into high gear in recent years, with important contributions from Leiden researchers. Astonishingly, we are currently capable of looking back to when the universe was only a few percent (400 million years) of its present age of 13.8 billion years. The young starbursting galaxies seen at these early times are dramatically different than the familiar present-day galaxies.

The enormous progress was made possible by deep near-infrared observations from space and from the ground. In particular, the Wide Field Camera 3 (WFC3) camera aboard the Hubble Space Telescope (HST) has revolutionized the field. The low foreground emission from space, high spatial resolution, and large field of view make WFC3 superbly efficient to detect the faint near-infrared light of distant galaxies. Near-infrared sensitivity is key. The most distant star forming galaxies are bright at rest-frame ultraviolet (UV) wavelengths but the light is stretched into the near-infrared by the time it reaches earth due to the expansion of the universe. Nearly all modern searches for very distant galaxies rely on identifying the Lyman Break – the strongest spectral feature of young star forming galaxies – to determine whether a source is at high redshift (see Figure 1). Using this technique, Leiden staff member Bouwens recently compiled all large extragalactic surveys with HST to find more than 700 candidate galaxies at redshift $7 < z < 10$ (750 – 500 million years), a huge increase from the dozen or so galaxies that where known before WFC3. This finally made it possible to chart the global evolution of the galaxy population at early times. The emerging picture is that the galaxies build up extremely rapidly in the first billion years, but also that the bulk of the total cosmic star light is emitted by ultra-faint galaxies below the detection capability of Hubble.

A special role in all of these studies is played by the diminutive Spitzer Space Telescope. Despite its 90cm(!) mirror Spitzer excels at detecting high redshift galaxies. Spitzer's mid-Infrared Array Camera (IRAC) is the currently only instrument capable of measuring light in the 3 – 5 micron range, which captures the rest-frame optical light of galaxies at $4 < z < 10$. The rest-frame optical is needed to determine the total stellar mass formed, whereas the rest-frame UV observed with HST is used to determine the instantaneous star formation rate. Together they provide a measure of the stellar growth rate of galaxies, which is a key datum for testing theoretical models of galaxy formation. A particularly surprising result from studies with Spitzer/IRAC was the discovery of ubiquitous strong nebular emission lines (primarily Hα, Hβ, and [OIII]) in galaxies at redshift $4 < z < 8$. The nebular lines, powered by vigorous star formation, reveal themselves by producing extreme colors in the IRAC 3.6 and 4.5 micron filters (see Figure 2). Far from being just a nuisance – which distorts estimates of stellar mass for example – IRAC colors also carry valuable information about the strength and redshift of the emission lines. Leiden researchers Labbé, Bouwens, and students Smit (now Durham), Rasappu, and Roberts-Borsani (now UCL) have been at the forefront of using these data creatively to place improved constraints on the SFR distribution, dust attenuation, photometric redshifts, and ionizing photon production at $z > 4$. This is usually considered next-generation science, but we can get a sneak peek of it even today.

A new application of the extreme IRAC colors is to preselect bright high redshift galaxies with strong line emission for follow-up spectroscopy. Spectroscopy with the largest groundbased telescopes remains enormously important to guarantee that the redshifts are correct (a key uncertainty in interpreting all high redshift studies) and to study the stellar populations and AGN activity. Initially discovered by Leiden student Roberts-Borsani, during the past year three bright IRAC-selected galaxies were confirmed to lie at $z > 7.5$ through detection of

Lyman−α line emission with groundbased near-infrared spectroscopy. Two of the galaxies even constituted redshift distance records, of which the one by Labbé and Caltech collaborators was at an unprecedented z = 8.68. This is a remarkable result, because strong absorption of Lyman−α is expected at z > 7 due to the substantial fraction of neutral Hydrogen in the intergalactic medium. This transitional period, when neutral Hydrogen is ionized by galaxies and slowly becomes transparent to Lyman−α photons, is known as the reionization era. The latest result from Planck cosmic microwave background (CMB) data places the average redshift of reionization between z = 7.8 and z = 8.8. The unexpected detection of Lyman−α emission in a luminous galaxy at z = 8.68 may hint that reionization was patchy and perhaps occured earlier in the overdense regions that host the most luminous objects. The culmination of high redshift spectral measurements is the discovery earlier this year by Oesch (Yale) and Leiden astronomers Bouwens, Labbé, and Franx of an ultraluminous galaxy at a record breaking redshift z = 11.09 (400 million years after the Big Bang, see Figure 3). The redshift was determined from a detected continuum break in HST/WFC3 grism spectroscopy, demonstrating that massive galaxy build up was well underway before the peak reionization epoch. The infant galaxy had already produced a billion solar masses in just a few hundred million years. While this is just one percent of our Milky Way's mass in stars, the galaxy is forming stars at a rate about 20 times greater than the Milky Way does today, making it bright enough for Hubble to determine its distance. In fact, the extreme brightness was a great surprise as earlier observations and theoretical work had suggested that such bright galaxies should not exist so early in the Universe. The existence of this source remains somewhat of a mystery for now.

Early universe research is a competitive and fast moving field, with no signs of slowing down. Current facilities are pushing the frontier to fainter limits (e.g., with the Hubble Frontier Fields, which use the magnifying effect of gravitational lensing by clusters of galaxies) and to much wider ~ degree-scale areas to probe the rarest most luminous "monster" galaxies (with leading contributions from the UltraVISTA survey co-led by Franx). The Atacama Large Millimeter/submillimeter Array (ALMA) is only just beginning to determine the dust obscuration and gas properties of galaxies at the highest redshifts, and bigger advances are a few short years down the road. To be launched in 2018, the James Webb Space Telescope (JWST) stands to revolutionize studies of the earliest galaxies. JWST will image sources to fainter limits and higher redshifts than possible with HST, potentially accounting more than half the starlight of the galaxies responsible for reionization and finding the first galaxies to form in the early universe. JWST's sensitive rest-frame ultraviolet-to-optical spectroscopy will easily detect the strong emission lines, as inferred from current Hubble + Spitzer photometry, promising robust estimates of the star formation rate, gas phase metallicity, and ionization state. Shortly after, next-generation groundbased telescopes, such as the 39m European Extremely Large Telescope (E-ELT), will start detailed spatial and spectral resolution follow up of galaxies discovered by JWST. Sensitive spectroscopy with future multi-object spectrographs, combined with 21cm line surveys to study the neutral gas (e.g., with the Square Kilometer Array) will then provide a complete picture of how the universe transitioned from the earliest 'Dark Ages' shortly after the Big Bang, via the first stars and galaxies, through reionization, to the diverse galaxy population of the present day universe.

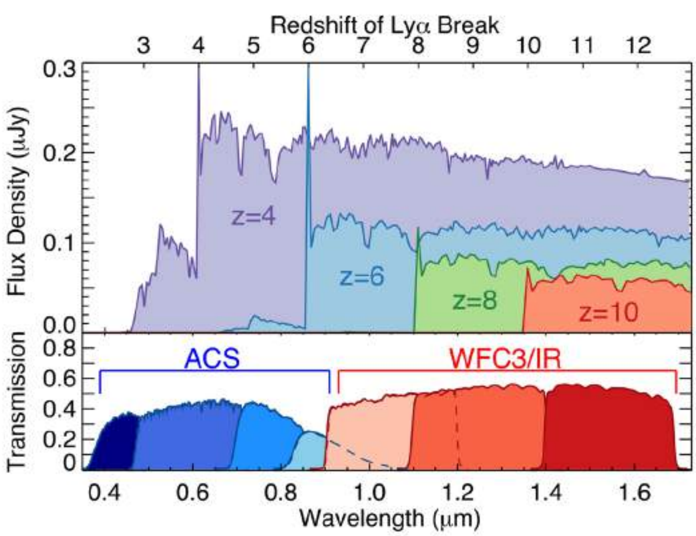


Fig.1a: Model spectra shown at several different redshifts. The model is a constant star forming stellar population with an age of 100 million years and no dust. The sharp edge of the spectrum, the Lyman break, arises due to absorption below rest-frame 912A by hydrogren in the stars and below rest-frame 1216 Å due to Lyα line absorption in systems along the line of sight. The feature is so strong it can be located simply by taking images in multiple filters and determining where the light of distant galaxies disappears or drops out (hence the alternative name ''Drop-out galaxies''). Filter response curves of 7 filters of the Hubble Space Telescope optical (ACS) and near-infrared (WFC3) cameras in comparison.

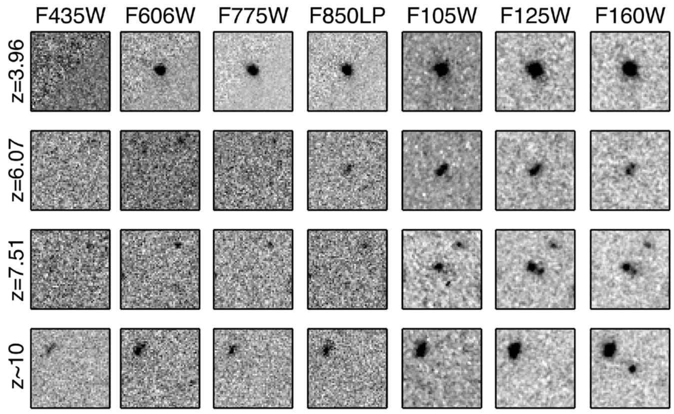


Fig.1b: Image stamps (3x3 arcseconds) in the same 7 HST filters for example galaxies at redshift z ~4, 6, 8 and 10. Figure adapted from Finkelstein et al. 2015.

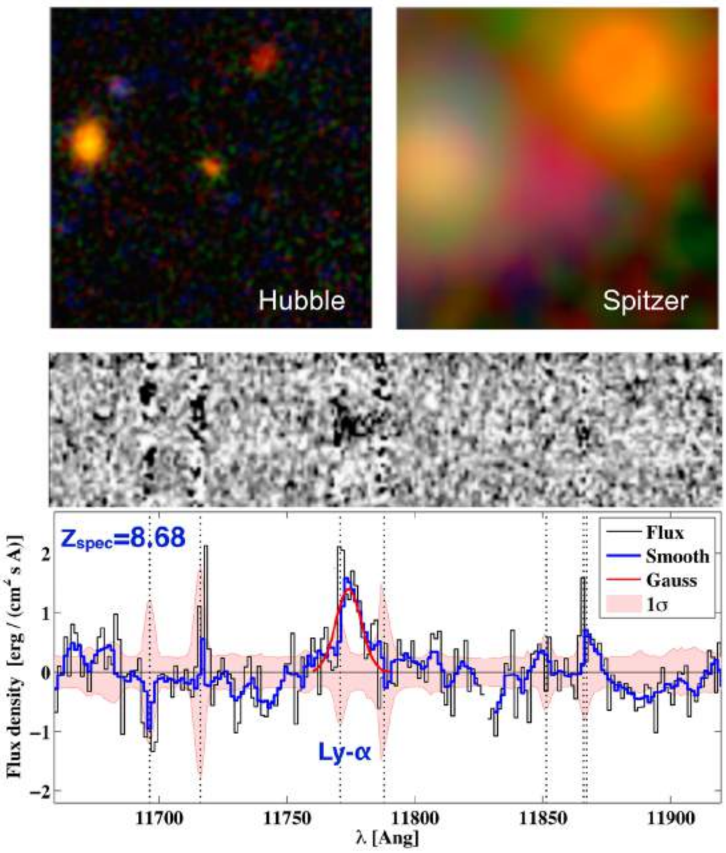


Fig.2: The most distant galaxy EGS8p7 spectroscopically confirmed with a detected Lyα line at z=8.68, found initially on the basis of a suspected spectral Lyman break around 1 micron combined with a red color in Spitzer/IRAC imaging. Top left: The Hubble Space Telescope WFC3 image of EGS8p7 located in the CANDELS AEGIS survey field. Top right: Spitzer/IRAC imaging of the same region. The red color, due to a flux excess at 4.5 micron relative to 3.6 micron, is caused by very strong [OIII] and Hβ line emission boosting the 4.5 micron filter measurement. Bottom: a 4 hour spectrum taken with the MOSFIRE spectrograph on the Keck telescope from Zitrin et al. (2015). The full 2D spectrum is shown in the top panel, while the optimally extracted 1D spectrum is shown on the bottom. The red shaded area represents the 1D flux uncertainty, while the dark red line shows a best-fit Gaussian line model. The detection of Lyα at such extreme redshift (in the epoch of reionization) was surprising due to the expected absorption by the partially neutral intergalactic medium.

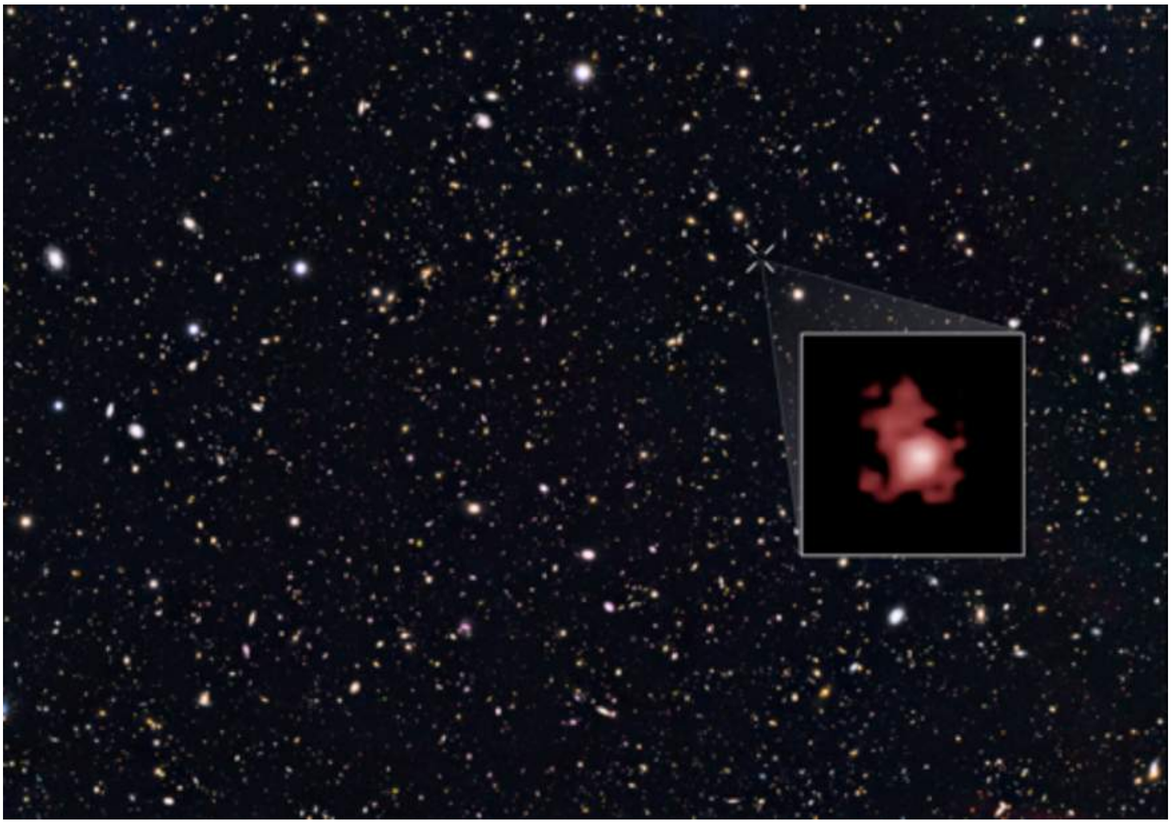


Fig.3: The position of the most distant galaxy GN-z11 discovered so far within a deep sky Hubble Space Telescope survey called GOODS North. The image shows tens of thousands of galaxies stretching to enormous distances and hence far back into time. The remote galaxy GN-z11, shown in the inset, was measured to be at an unsurpassed redshift z=11.09±0.1. This corresponds to only 400 million years after the Big Bang, when the Universe was just 3 percent of its current age. It belongs to the first generation of galaxies in the Universe. Surprisingly, the galaxy is enormously bright and formed stars at a rate 20 times higher than the Milky Way today. It remains a mystery how galaxies grew so fast so early on in the universe.

Resolving the sky - integral **field spectroscopy** using **MUSE**

Jarle Brinchmann

Spectroscopy is an essential method for studying the properties of celestial sources, and the traditional way to do this has been to take a picture of the sky and select which objects you want to obtain spectra of based on that image. While this approach has been a major pillar of astronomical research over the years, it does have strong limitations: only relatively bright objects are targeted, spectra of closely spaced objects are often impossible to obtain in one go, and spatially resolved information might not be obtained.

The panoramic integral field spectrograph MUSE, which saw first light on the VLT in 2014, has changed this fundamentally and has seen a strong involvement by NOVA and by Leiden astronomers through their participation in the Guaranteed Observing Time program of the instrument consortium.

What sets MUSE apart is that it does away with the image – instead it takes in effect images with pixels 0.2”x0.2” in size across a field of view of 1’x1’. But rather than a simple image in each pixel, it provides a full spectrum, a total of 90,000 of them. This type of instrument, an integral field spectrograph – in the case of MUSE in fact 24 integral field spectrographs working together, has been around for more than 30 years, but the field of view, stability and throughput of MUSE makes it stand head-and-shoulder above other facilities of its kind.

Locating the faintest galaxies in the sky

A major challenge for the traditional approach of spectroscopic surveys is to survey galaxies with very strong emission lines – these may be very faint in an image taken with a broad filter, but yet be a very active galaxy and hence of great interest. In the distant Universe these are typically known as Lyman-alpha emitters (LAE) and MUSE offers an entirely new way of finding and studying these sources.

The potential of this new approach was demonstrated with an ultra-deep MUSE observation of the Hubble Deep Field South, published in Bacon, Brinchmann et al (2015). This 27hr exposure obtained during commissioning increased the number of galaxies in the field with known distances by an order of magnitude. This provided a plethora of star forming galaxies across cosmic time - from a tiny dwarf galaxy with redshift z~0.1 with stellar mass less than 10^6 solar masses to a wealth of distant LAEs. Despite the extreme depth of the HST image, a total of 26 LAEs were found that could not be seen in the HST image – a remarkable, and somewhat unexpected, harvest (see Figure 1).

These observations have shown the viability of this new observational paradigm and a series of follow-up observations are going on that will greatly extend these results.

The spatial extent of Lyman-alpha emitters

Prior to MUSE, the size of the Lyman-alpha emitting region in distant star-forming galaxies was mostly known in a statistical sense, based on an analysis of a stack of narrow-band images of such galaxies, pioneered by Steidel et al (2011), although an early, deep, long-slit observation by Rauch et al (2008) had provided clear indications that many distant galaxies had extended Lyman alpha emitting region. The reliance on statistical studies was unfortunate, because the relative size between the Lyman-alpha emitting region and the rest-frame ultraviolet (UV) bright region in a galaxy can provide us valuable information on the amount of gas around a galaxy – a quantity otherwise very hard to measure.

The UV and Lyman-alpha photons originate in the same region, but while the UV photons travel essentially straight to us, Lyman-alpha photons scatter in any neutral surrounding gas and might there diffuse a significant distance out from the UV emitting region before they escape and travel to us. As a consequence, the size of the Lyman-alpha emitting region will typically be much larger than the UV emitting region. Measuring this difference had proved difficult, however, with the existing instrumentation.

Enter MUSE and its wide-field capability. The deep observations with MUSE of the Hubble Deep Field South mentioned above, turned out to be extremely sensitive to extended Lyman-alpha emission. In Wisotzki et al (2016), we showed that with MUSE it was for the first time possible to study in a systematic manner the Lyman-alpha halos of distant galaxies individually and remarkably enough almost all distant star-forming galaxies appear to show this extent. In fact we found that 21 out of the 26 objects suitable for study showed this extended halo, and the remaining are consistent with having the same halo although they are too faint to be detected in our observations.

This result indicate that galaxies at z>3 are always surrounded by a large amount of neutral gas – not necessarily a surprising conclusion but one that is in strong contrast to what is seen in the local Universe and a very good illustration of the power of this new instrument on the VLT.

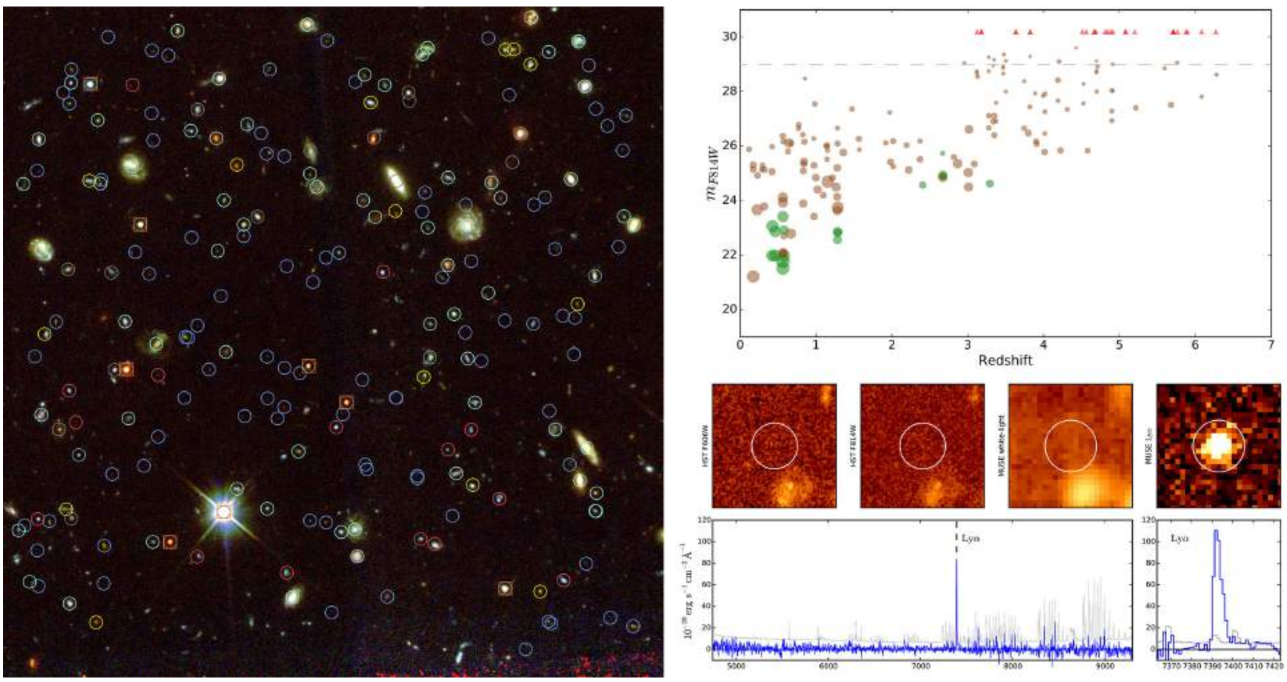


Fig. 1: Left: The location of objects with redshift determined with the MUSE observations of the Hubble Deep Field South overlaid on the HST colour image of the field. The redshift distribution is shown in the top right panel with redshifts known before MUSE in green, and objects seen with MUSE that are invisible in the ultra-deep HST image are shown with the red triangles. An example of this latter class of objects is shown in the bottom figure where the HST colour and single-band image are shown as two postage stamps, while the MUSE narrow-band image over the Lyman-alpha line, seen in the spectrum at the bottom, is shown in the last postage stamp.

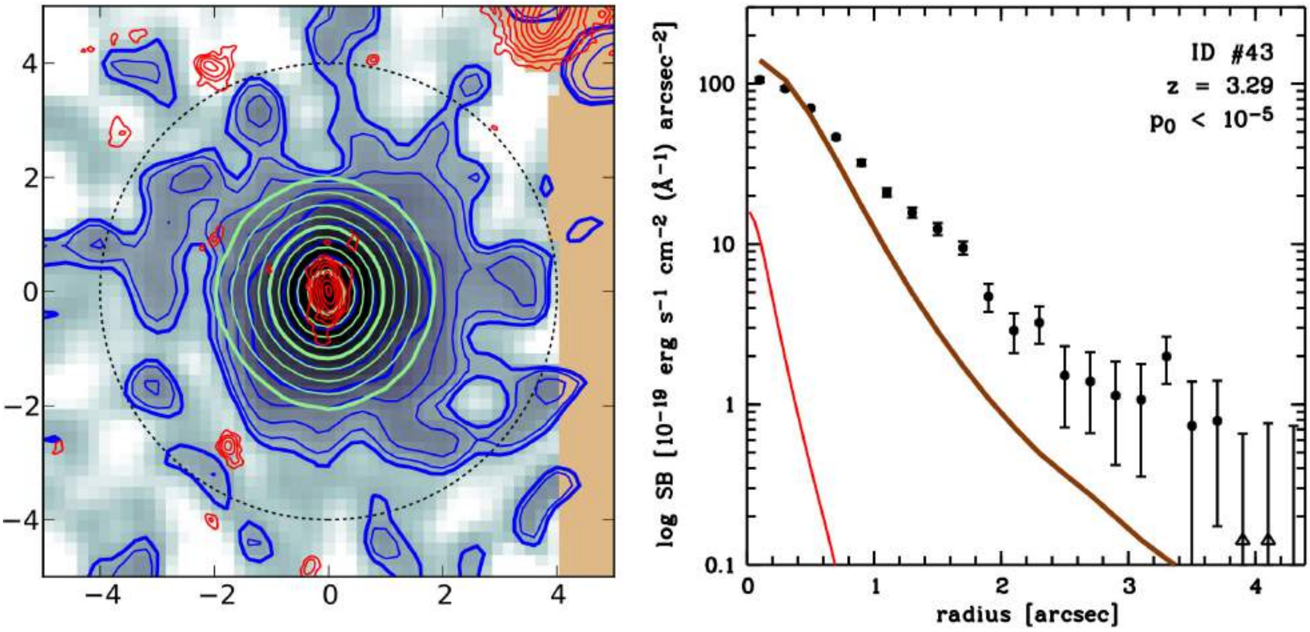
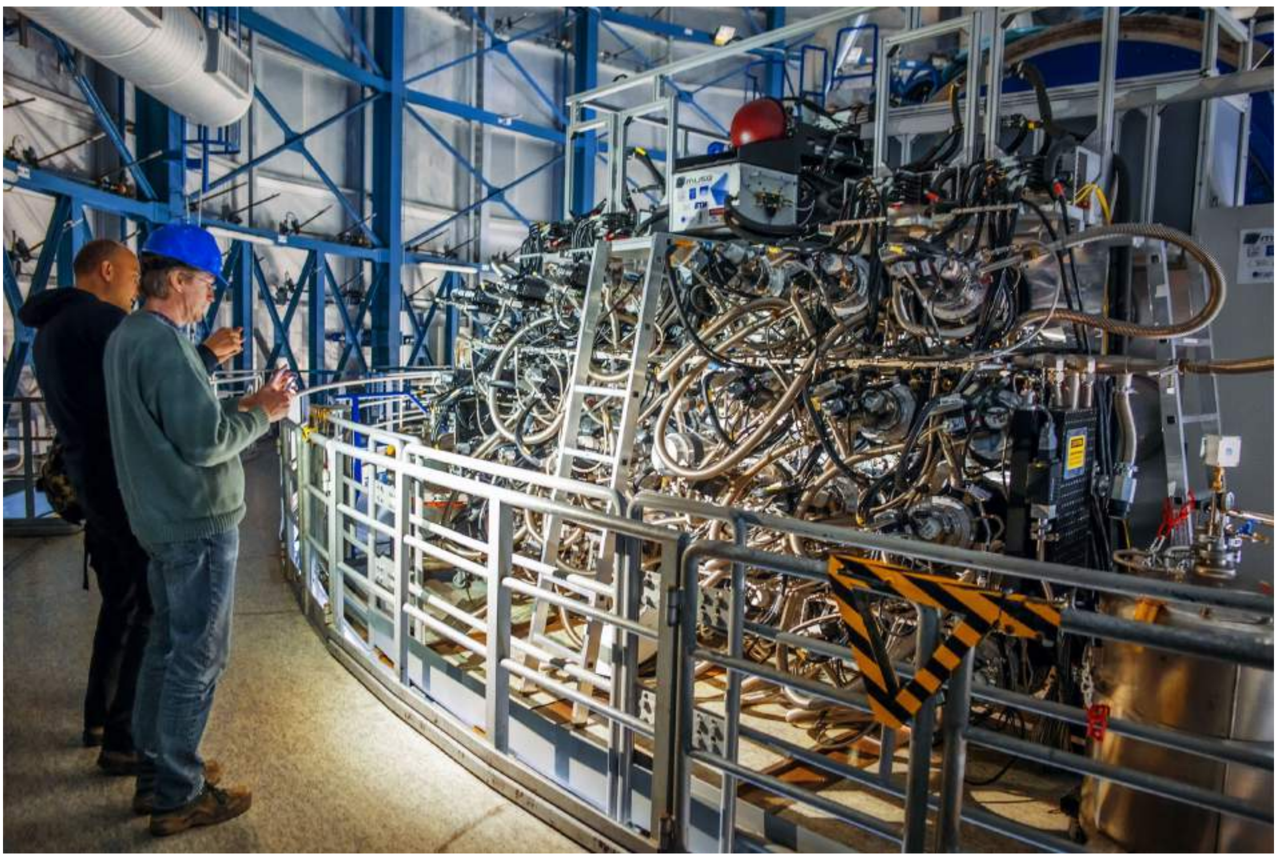


Fig. 2: Left: The blue scale with blue contours show the Lyman-alpha emission in this z=3.29 galaxy. The green contours show the UV emitting region convolved from the relevant HST image to the seeing of the ground-based data from MUSE. Clearly the Lyman-alpha region is larger than the UV emitting region. Right: This is quantifies the result from the left panel by showing azimuthally averaged radial profiles of the Lyman-alpha emission (black points with error-bars), compared to the radial profile of the UV emission convolved by the ground-based seeing (brown line). Figure adapted from Wisotzki et al (A&A 587, 98; 2016).



MUSE at the Very Large Telescope.

One flew over the **cuckoo's nest**

Simon Portegies Zwart

The dynamic outer Solar System

The Solar system is composed of the Sun, a dozen planets, a few hundred moons and thousands of comets. Least prominent are the planetesimals, and among those even less pronounced is the debris, as it is often called, at the Solar System's outskirts. These outer Solar System objects, however, can teach us much about the Solar System history.

The planetesimals that populate the outer parts of the Solar system can be divided in roughly two families. Furthest away, more than 1000 AU, and almost extending to the nearest stars is the Oort cloud. Further in, but still outside Neptune's orbit and extending to about 100 AU is the Egeworth-Kuiper belt. The orbits of the planetesimals in the Egeworth-Kuiper belt are not static, but are perturbed quite characteristically by the outer most giant planets, Uranus and Neptune. In the orbital distributions (in particular the eccentricity and inclination) one can easily recognize the over-populated resonant and under-populated interfering orbital families. Planetesimals tend to pile-up in resonant orbits with the giant plants. Objects with an orbital period that has integer nominator and denominators, such as 1/2, or 3/5, are more stable than real-numbered orbits. The dwarf planet Eris with its tiny moon Disnomia (mother and daughter in Greek mythology roam the skies as incarnations of the wicked fairy Maleficent) is such an object that got its wide and eccentric orbit from being bullied around by Neptune.

The planetesimals beyond about 100 AU are sufficiently far from the plants that their gravitational pull is negligible, and their orbits remain unaffected for the lifetime of the Solar System. This is illustrated in Fig. 1, where we plot the time scale on which a close encounter perturbs the outer most objects in the Solar System. The nearby stars and the global galactic tidal field only starts to affect the orbits of planetesimals further away than about 1000 AU from the Sun. This makes the region between about 100 AU and 1000 AU a safe zone in which planetesimals are unaffected by internal or external influences. The orbits of the planetesimals in this regime remain unaffected for the lifetime of the solar system, and therewith form a frozen record which we can use to reconstruct the history of the solar system.

Only a few planetesimals are known that orbit between about 100 AU and 1000 AU around the Sun, these include Sedna and the recently disiscovered 2012 VP113. Interestingly enough both planetesimals orbit between the Edgeworth-Kuiper belt and the inner Oort cloud, and they do not seem to belong to any known family of objects. The orbital characteristics of both planetesimals still bear the information about how they were introduced. We can therefore use them as some sort of time machine to study the early evolution of the Solar System.

Sedna and the family

Last year a search for similar objects successfully revealed about a dozen planetesimals with orbits similar to Sedna. Although it is still uncertain if they really form a family, we call them Sednitos, after the first object discovered. The orbital similarities among the Sednitos are hard to explain; they cannot have migrated from the Egeworth-Kuiper belt nor from the Oort cloud, and the chance that a dozen objects would accidentally arrive at similar orbits is negligible. The dozen objects in the Sednito region require an alternative explanation, but each of them fails spectacularly in explaining the common characteristic in their orbits. There is one remaining possibility: Sedna and family could have been captured by the Sun, from the Edgeworth-Kuiper belt of another star.

Reconstructing the abduction

An encounter between two stars is a deterministic process, meaning that we can precisely calculate the trajectories of both stars from Newton's law of motion. So long as the two stars dominate the dynamics, the

encounter parameters remain preserved and the effect of the encounter leaves a characteristic imprint on the distributions of the planetesimals in orbit around the two stars. The calculation itself however, becomes so complicated that a computer is required for integrating the equations of motion of both stars together with their minions.

The difficulty in reconstructing the encounter that injected the Sednitos into the solar system however, hides in the unknown conditions from before the two stars met. In principle, we can find those conditions by performing a large number of encounter simulations and study the distribution of orbital parameters of the transferred planetesimals. The main difficulty of this approach hides in the dimensionality of the problem. The encounter between two stars can be uniquely characterized by a total of 16 independent parameters. Systematically searching this parameter space is a hopeless undertaking, but we have the computer to map parameter space.

In Fig. 2 we present a sketch of the encounter between the Sun with early planetary disk (red) and the encountering star (blue). An animation of the encounter is available at: https://www.youtube.com/watch?v=AQfI5kHaU

When and where did the encounter take place?

We reconstructed the encounter, which resulted in a star that delivered Sedna, which was almost twice as massive as the Sun. In Figure. 3 we present the reconstructed encounter. It must have had a planetesimal disk that extended to beyond 160 AU, approaching the Sun with a velocity of 4.3 km/s, and passing at a distance of 230 AU. The perturbations induced upon the solar system penetrate to 40 AU. Planetesimals beyond this regime will have acquired a particular jolt, leading to a sharp cut-off in the Sun's Edgeworth-Kuiper belt.

This cut-off in the Edgeworth-Kuiper belt matches the requirement for the Nice model to explain the epoch of late heavy bombardment, evidenced by the many craters from this epoch on the lunar surface. This event is anticipated to have occurred some 200 to 700 Myr after the formation of the solar system. As a consequence, the encounter with the other star should have occurred before the epoch of planetary migration. This is consistent with the most likely moment when such an encounter could have taken place; namely when the Sun was still a member of its birth cluster.

It is only in a relatively dense star cluster that an encounter between the sun and another star is likely to take place (see Fig. 1). The probability of such an encounter increases with the mass and stellar density of the cluster. Such clusters tend to dissolve due to stellar mass loss and the galactic tidal field within a few 100 Myr. Some of these solar siblings may be floating around in the Solar neighborhood and can potentially be found back with the Gaia satellite.

The consequences of the encounter

Apart from having reshaped the solar system's outer regions, more than 2000 planetesimals have been transferred from the other star to become bound to the young Sun. About half of them in orbits similar to Sedna. The planetesimal exchange model therefore predicts that there should be about a thousand planetesimals with orbital parameters similar to Sedna. Most of them are probably considerably smaller than Sedna, and therefore even harder to find.

The rest of the captured planetesimals are deposited within the orbit of Neptune. There they will be scattered by the giant planets. Most of them were probably ejected long ago from the solar system, but some of these could also have hit Earth. In fig. 3 we present the results of these calculations, in the predicted distribution of Sednito-like objects in the outer parts of the Solar System. For completeness we over plot the observed objects (as diamonds)

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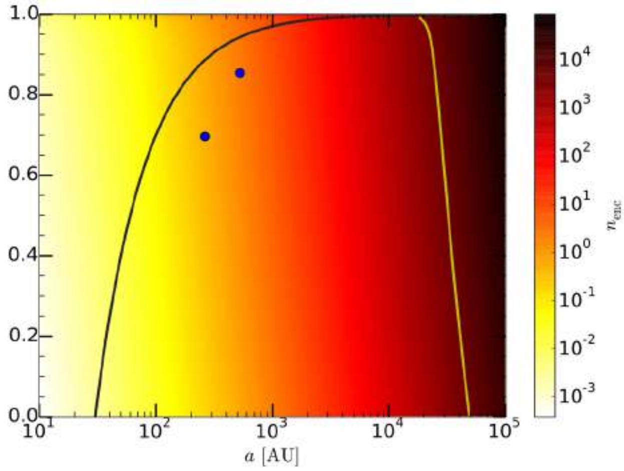

Fig. 1: The fragility of the Solar System in the Galactic field. The shades represent n_{enc}: the probability density distribution for the number of encounters that affect the orbits in the Solar System to a given semi-major axis a and eccentricity e. Here we adopted a stellar density of n = 0.20 stars/pc^3 , a velocity dispersion of v = 30 km/s and the typical mass of an encountering star of M = 0.5 M_{Sun}. The solid black curve and the two bullet points give the Neptune's perturbing distance. The two bullet points give the orbital parameters of Sedna (Brown et al., 2004) and 2012VP 113 (Trujillo & Sheppard, 2014). The yellow curve gives the distance to which the Solar System was perturbed (by 1 % of its velocity at apohelion) due to the recent encounter with the 0.15 M_{Sun} binary star WISE J072003.20-084651.2, which grazed the Solar System, but clearly did not come in close enough to perturb the inner Oort cloud.

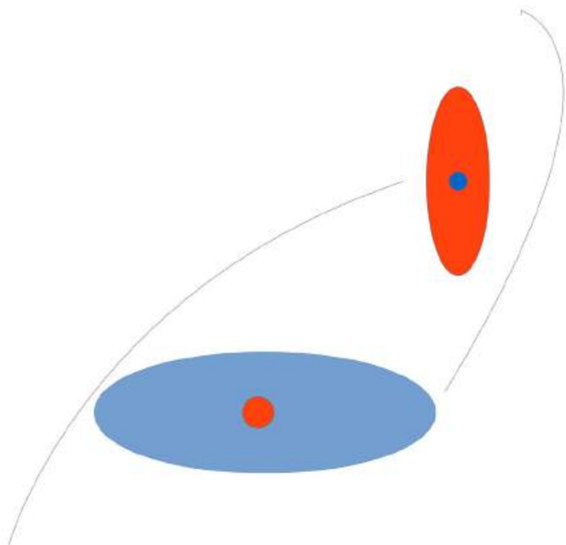

Fig. 2: Sketch of the encounter.

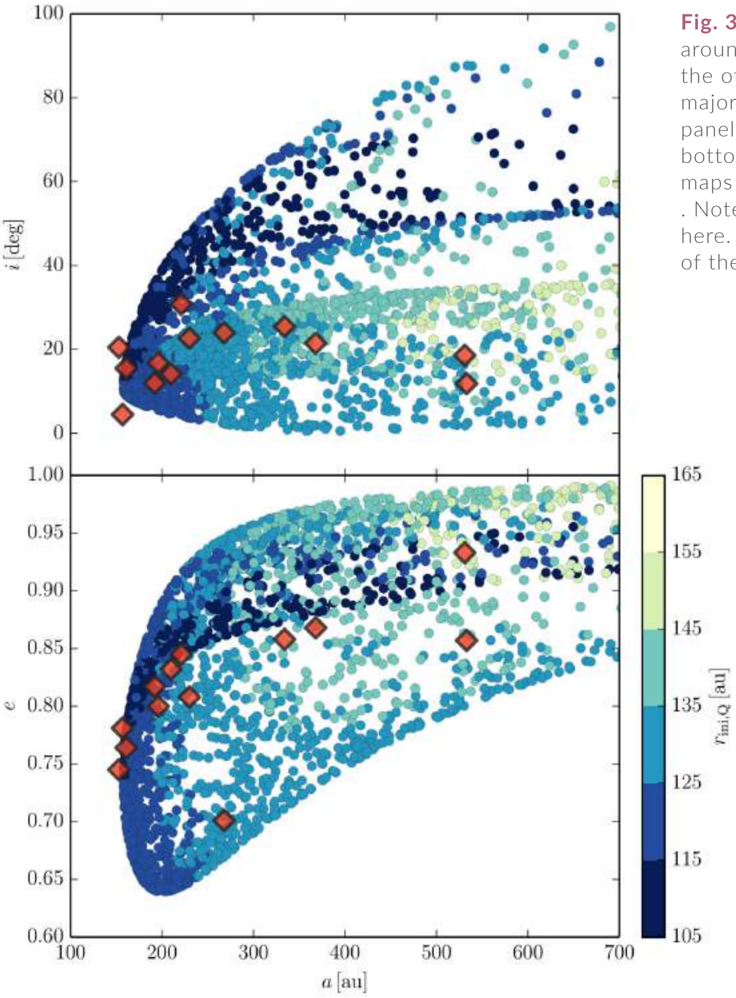

Fig. 3: Distribution of the planetesimals captured around the Sun during the preferred encounter with the other star. Along the x-axis we present the semi-major axis a of the captured planetesimals. The top panel gives the inclination i along the y-axis, and the bottom panel gives the eccentricity e. The color scale maps the initial radius in the other star's disk, $r_{ini,Q}$. Note that the simulated particles are not weighted here. The red diamonds give the observed positions of the Sednitos.

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Holes in stellar **halos**

Direct **exoplanet imaging** with the vector-APP coronagraph

Frans Snik & Matthew Kenworthy

The several thousand indirect detections of planets around stars other than the Sun have led to a new breed of astronomer: the kind that wants to see as little starlight as possible. The goal of these astronomers is to directly detect and analyze the light from such exoplanets, and thus find out what they are made of, how they are formed, and whether they support life. However, to be able to answer these exciting questions, they need to overcome the tremendous challenge of suppressing the light of their parent stars which are millions to billions of times brighter. Even for telescopes with perfect optics, the halo of starlight overwhelms the signal from any planet. Researchers from the High-contrast Imaging Group of Leiden Observatory are therefore developing revolutionary optical techniques that create dark holes in the stellar halo to reveal the planets. Their so-called vector-APP coronagraph is currently able to discover and characterize exoplanets that are 100,000 times fainter than their parent star, at the closest-possible separation at which the largest telescopes can discern them.

Coronagraphy of other stars than the Sun

The optical technique of suppressing starlight is generally called coronagraphy, as it is derived from techniques to image the fainter outer atmosphere - the corona - of the Sun. Most types of coronagraph block the light from the star itself at an image plane of the telescope, which also suppresses the surrounding halo. However, this technique relies on very accurate positioning of the image of the star onto a so-called focal-plane mask. Telescope vibrations move the star off the mask and easily degrade the performance of such coronagraphs. At Leiden Observatory, researchers champion a different type of coronagraph: one that does not just block the starlight, but redistributes the light in the halo such that dark holes appear right at the location where they want to look for planets. The Apodizing Phase Plate (APP) coronagraph (Kenworthy et al. 2007) introduces a precisely calculated and specific aberration to the pupil of the telescope. In its first incarnation, the APP consists of a glass plate with the phase pattern carved out from one of its surfaces, which is then inserted in a pupil-plane location of an imaging instrument. The Point Spread Function (PSF) of the telescope plus instrument is then modified such that the diffraction halo on one side of the star disappears due to destructive interference, see Fig. 1. The main benefit of pupil-plane coronagraphs is that they work regardless of any telescope vibrations, and it even permits moving the image of the star around on the detector for background subtraction at infrared wavelengths.

Discovery of a baby planet

One version of the APP coronagraph has been installed in the adaptive-optics-augmented infrared camera NACO at the 8.2-m Very Large Telescope in Chile (Kenworthy et al. 2010). To exploit the unique capabilities of the APP, Matthew Kenworthy (Leiden Observatory) teamed up with astronomers from ETH Zurich (Switzerland) to hunt for planets around nearby stars. The observations of the star HD 100546 found unambiguous and direct evidence of a planetary companion, for now named HD 100546 b, see Fig. 2 (Quanz et al. 2015). Both the star and its planet are still very young (~10 million years), and in fact, HD 100546 b is the youngest known infant planet that can be studied directly. Its presence at a large separation from its parent star (~50 AU) is yet unexplained by current models of planet formation. Moreover, the planet appears to have a radially extended emission feature (see Fig. 2), which could be indicative of material that is still surrounding and accreting onto the planet.

Liquid crystals to the rescue!

While the APP coronagraph has been delivering exciting scientific results, its performance is still somewhat limited. First of all, the dark hole only appears on one side of the star, whereas planets can reside on either side. Secondly, the APP only works optimally at one single wavelength. Also, the depth of the hole is limited as extreme phase patterns cannot be manufactured using the original manufacturing technique. To solve these issues, Snik et al. (2012) introduced liquid-crystal techniques to evolve the APP into the vector-APP coronagraph. The main difference with the APP is that the vector-APP utilized the so-called geometric phase instead of the well-known classical phase. This geometric phase is imposed by an orientation pattern of liquid crystals, as sketched in Fig. 1, and is inherently achromatic: this pattern does not change with wavelength. The liquid crystal properties are chosen such that they obtain a retardance (phase difference for two perpendicular polarization states) of half a wave. The patterned liquid crystals then impose a positive phase pattern upon right-handed circular polarization, and a negative phase pattern upon left-handed circular polarization. By splitting the circular polarization states, the vector-APP therefore produces two PSFs, that contain dark holes on either side. Moreover, state-of-the-art liquid crystal patterning techniques permit the very accurate production of extreme phase patterns that yield very deep dark holes over unprecedented wavelength ranges (up to over an octave).

From the lab to the telescope

To build continuously improved versions of the vector-APP coronagraph, the Leiden High-contrast Imaging group is collaborating intensively with the group of Michael Escuti at North Carolina State University (USA) that is pioneering novel liquid-crystal optics (Escuti et al. 2016). Leiden PhD student Gilles Otten led the development of a vector-APP prototype for visible light (Fig. 3), and demonstrated its excellent performance in the lab in Leiden (Otten et al. 2014). Particularly impressive was the presence of dark holes over a wide range of wavelengths, see Fig. 4. After this success, the team was very eager to take the vector-APP to the telescope. In 2015, they were given the very exciting opportunity to install an infrared version of the vector-APP coronagraph in the MagAO instrument connected to the 6.5 Magellan Clay telescope in Chile. Within three months they went from design to installation, and in May 2015 they performed the first test observations. The first light images already constituted breakthrough on-sky performance, see Fig. 5. Analysis of this data shows that this vector-APP coronagraph delivers a contrast of 1:100,000 at very small separations from the star (~2.5 telescope diffraction widths $/D$), and thus outperforms any other current high-contrast imaging instrument. A second vector-APP device was installed inside MagAO, and contained a highly experimental phase pattern to clear out a full 360° region around the star in Fig. 6.

The path towards finding life on Earth-like exoplanets

The vector-APP coronagraph is now an established component to enable direct observations of exoplanets. Leiden astronomers are currently using it to image exoplanets with unprecedented sensitivity. However, to directly detect and study exoplanets that resemble those of our own solar system, the contrast performance needs to be further enhanced. In 2015, Frans Snik was awarded a prestigious ERC Starting Grant (1.5 M€) to develop new techniques and technologies to achieve an overall contrast as extreme as 10^{-9}, by combining improved versions of the vector-APP coronagraph with other optical modalities like adaptive optics, (focal-plane) wavefront sensing, polarimetry, and spectroscopy. Moreover, the expanded Leiden research group will exploit their new techniques for science observations with current telescopes, and prepare for future telescopes like the 39-m European Extremely Large Telescope that is currently under construction in Chile. The vector-APP is already a baseline coronagraph for the E-ELT instrument METIS, for which Leiden Observatory is the PI institute, and will be installed in EPICS, the second generation extreme adaptive optics instrument for the VLT. The ultimate goal of the group is to establish a fully integrated concept for EPICS, which contrast performance and spectro-polarimetric characterization functionality will enable the very first direct observations of rocky planets in the habitable zones of nearby stars. Perhaps EPICS will even see signs of habitability on an Earth-like planet orbiting a neighboring star within the next two decades.

Astronomical technology with down-to-Earth applications

The vector-APP coronagraph exploits liquid-crystal technology that was originally developed for more Earth-bound applications, like displays for computers, TVs and smartphones. By pushing the instrumentation for direct imaging of exoplanets to the limits (and beyond), Leiden astronomers also invent spin-off technology with applications that range from air pollution measurements to biomedical imaging. For instance, the instrumentation group of Leiden Observatory applies their polarization and liquid-crystal techniques to measure the effects of small particles in the Earth's atmosphere on our health and on our climate, from platforms ranging from satellites to smartphones (Snik et al. 2014). Frans Snik and Michiel Rodenhuis engaged in a very special collaboration with artist Daan Roosegaarde and his studio. Together with the NCSU group they built an installation that projected a rainbow on one of the arches spanning over the Amsterdam Central train station, every day after sunset in 2015 (see Fig. 7). This rainbow took on exactly the right shape with >95% efficiency across the visible spectrum thanks to a dedicated grating based on the same liquid-crystal technology as the vector-APP coronagraph.

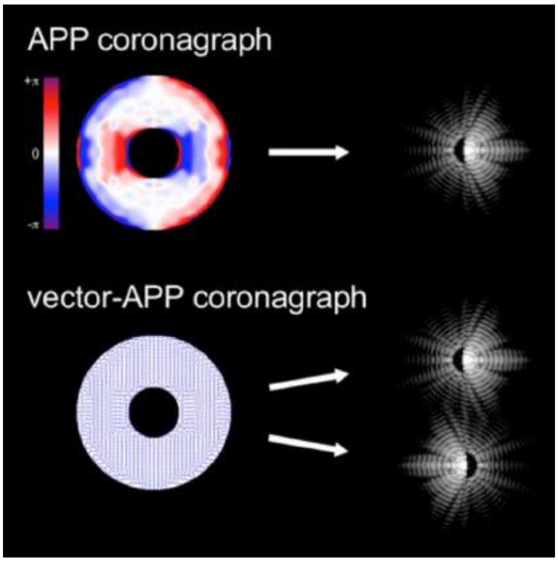
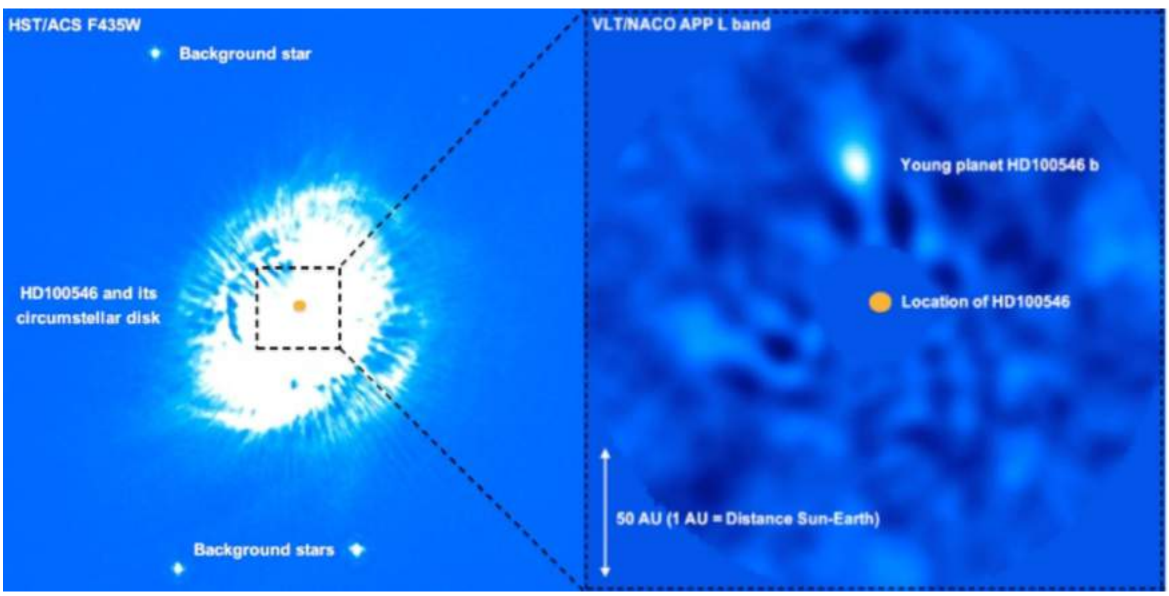


Fig. 1: Schematic representation of the functionality of the Apodizing Phase Plate (APP) coronagraph and the vector-APP coronagraph. The APP phase pattern in the pupil (that is partially obscured by the telescope's secondary mirror) generates a Point Spread Function (reproduced here in logarithmic scale) with a dark hole on one side. For the vector-APP coronagraph the phase pattern is converted into an orientation pattern of liquid crystals, which, after splitting of circular polarization states, yields PSFs with dark holes on either side. Phase pattern design by Christoph Keller.

Fig. 2: Direct image of the young planet HD 100546b next to its parent star. This observation is enabled by the APP coronagraph installed at VLT/NACO. Adapted from Quanz et al. (2015).



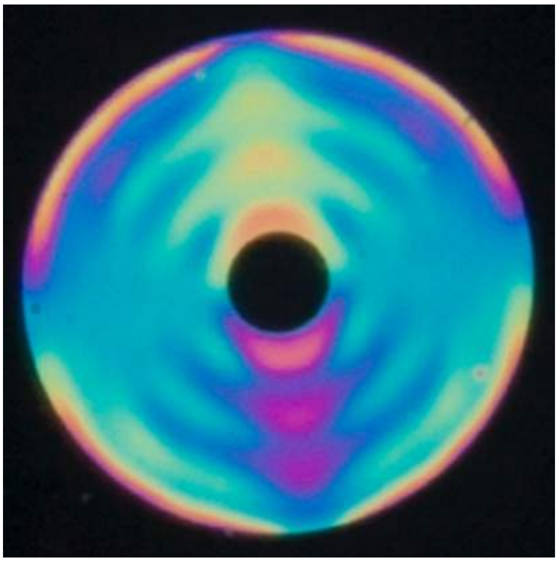


Fig. 3: Photo of the vector-APP prototype in the lab in Leiden. The device has an optical footprint of ~5.5 mm. The liquid-crystal pattern is converted into an intensity/color pattern by the two crossed polarizers that are sandwiched around the device. Photo credit: Gilles Otten.

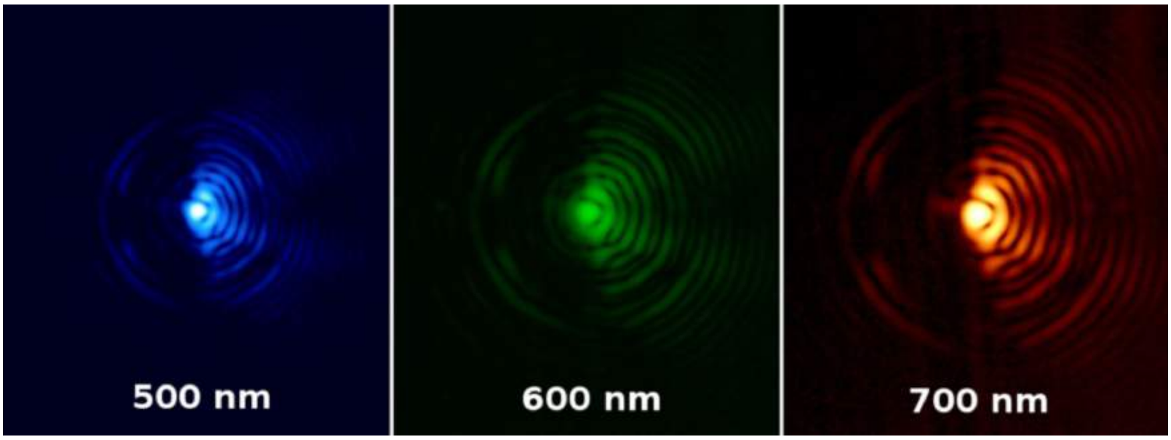


Fig. 4: Broadband performance of the vector-APP prototype as measured in the lab in Leiden. Adapted from Otten et al. (2014).

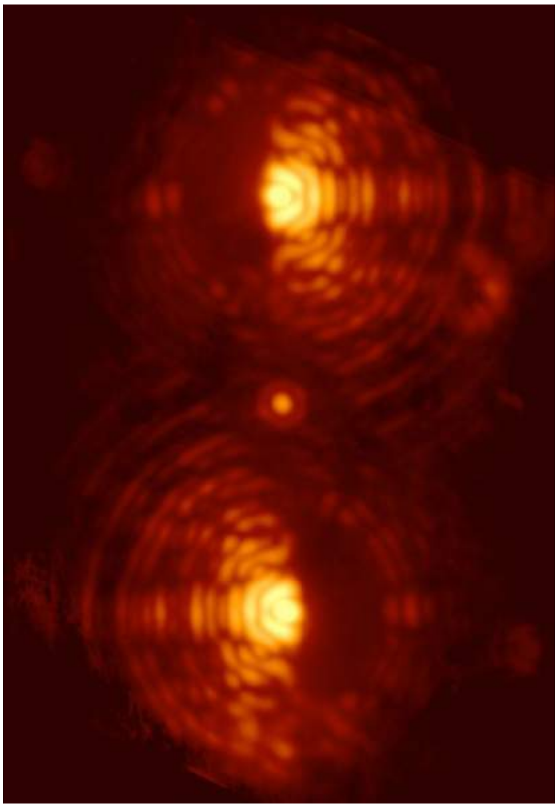


Fig. 5: Double image of the star Eta Crucis taken at 3.9 µm wavelength through the vector-APP coronagraph installed at MagAO on the 6.5m Magellan telescope. The two main images of the star exhibit D-shaped dark holes on complementary sides.

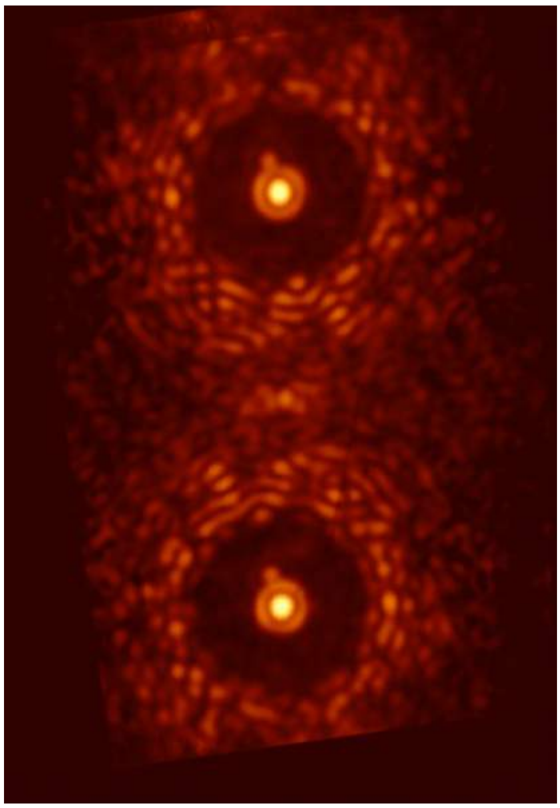


Fig. 6: Double image of the binary star beta Centauri taken through an experimental version of the vector-APP coronagraph installed at MagAO. Both images of the star contain a dark region that covers the complete 360 degrees around the central star. In both cases, the binary companion to beta Centauri is easily detected at the 11 o'clock position.

Fig. 7: Impression of the “Rainbow Station” art installation at Amsterdam Central train station by Studio Roosegaarde in collaboration with Frans Snik and Michiel Rodenhuis of Leiden Observatory, and the NCSU GPL group. The rainbow was visible after sunset every day in 2015, and was created by a grating that was built from the same liquid-crystal technology as the vector-APP coronagraph. Photo credit: Studio Roosegaarde.

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Zooming in on planet-forming discs with ALMA

Ewine van Dishoeck

Planets are found around nearly every star, but it is still not fully understood how they form and what controls their composition. To answer such questions, one needs to study their birthplaces: the rotating discs of gas and dust around young stars. But these discs are small and far from Earth, and the power of the Atacama Large Millimeter/submillimeter Array (ALMA) is needed to reveal their secrets. Van Dishoeck, Hogerheijde and their groups have used early ALMA data to zoom in on planet-forming discs for the first time on scales corresponding to the orbit of Saturn (~10 AU) to study their physics and chemistry.

Mind the gap: pinpointing planet construction sites

A special class of discs, called transitional discs, have a surprising absence of dust in their centres. Two main ideas have been put forward to explain these mysterious gaps. First, the strong stellar winds and intense radiation could have blown away or destroyed the encircling material. Alternatively, massive young planets in the process of formation could have cleared the material as they orbit the star. These two theories predict different distributions for the gas in the system.

The unparalleled sensitivity and image sharpness of ALMA have allowed van der Marel (Leiden cum laude PhD), van Dishoeck, Bruderer (Garching) and collaborators to map the distribution of gas and dust in a small sample of these transitional discs (Fig. 1). The images show that there are significant amounts of gas within the dust gaps. To the team's surprise, the gas also shows a gap, up to three times smaller than that of the dust: gas and mm-sized dust grains clearly do not follow each other.

These observational facts can only be explained by the scenario in which newly formed massive planets have cleared the gas as they travel around their orbits, but trap the dust particles in pressure bumps further out, as found in models by Leiden postdoc Pinilla. This provides the clearest indications yet that planets with masses several times that of Jupiter have recently formed in these discs. Further studies are now needed to determine whether more transitional discs also point towards this planet-clearing scenario. If so, ALMA can pinpoint where and when giant planets are being born in discs: ELT-METIS then knows where to look for them when it becomes operational around 2025.

A tunnel and a traffic jam

One of the mysteries surrounding transitional discs is how these systems can maintain a detectable warm dust component very close to the star despite the presence of a large planet-carved gap. Although such a double dust ring is naturally created by a planet clearing out the disc around its path, the inner disc should dissipate quickly onto the star. A team led by Pinilla and including Dominik (Amsterdam) has put forward the first plausible explanation for this phenomenon.

The clou is that the outer dust ring continuously feeds the inner disc with small dust grains. This feeding occurs in groups of particles which are held together by ice in the outer disc but fall apart into small dust grains when they cross the snowline and the ice sublimates. The newly developed models help explain the formation of Earth-like planets in the inner dust disc, which needs to survive long enough for protoplanets to grow.

Complex molecules finally detected in discs

Simple molecules like CO have been detected in discs for decades, but observations of the more complex molecules so widely observed in star-forming regions has proven elusive for protoplanetary discs. In 2015, two teams have detected for the first time the presence of complex organic molecules, the building blocks of life, in discs surrounding young stars using ALMA. These discoveries reaffirm that the conditions in the presolar nebula from which our Earth and Sun formed are not unique in the Universe.

The disc surrounding the young star MWC 480 has been found to contain large amounts of methyl cyanide (CH_3CN), a complex carbon-based molecule, in a study led by "Oberg (Harvard, former Leiden PhD) and involving Leiden postdoc Furuya. Both this molecule and its simpler cousin hydrogen cyanide (HCN) are detected in the cold outer part of the disc, in a region that is analogous to the Kuiper Belt. Cyanides are important because they contain carbon–nitrogen bonds, which are essential for the formation of amino acids, the foundation of proteins and the building blocks of life.

The methanol molecule (CH_3OH) has been detected in the disc surrounding the star TW Hya, in a program led by Walsh (Leiden VENI fellow). Methanol is thought to be the starting point for the formation of many complex oxygen containing molecules such as the simplest sugars. Until now, it was unclear whether these complex organic molecules can form and survive in the energetic environment of a newly forming Solar system, where shocks and radiation can easily break chemical bonds. The new ALMA data demonstrate that complex molecules not only survive but in some cases can even flourish. The chemical models developed by Walsh and Furuya to explain the ALMA data have greatly benefitted from experiments carried out in the Sackler laboratory for astrophysics at Leiden by Fedoseev, Chuang, Ligterink and Linnartz.

As these systems continue to evolve, it is likely that the organic molecules will be locked away in larger icy bodies or comets. Due to dynamical interactions, they can be transported to the terrestrial planet forming zones of discs where they then provide the seeds for life.

Detection of surprisingly abundant O_2 in comet 67P

Oxygen is the third most abundant element in the Universe, but the simplest molecular version of the gas, O_2, has proven surprisingly hard to track down, even in star-forming clouds, because it is highly reactive and readily breaks apart to bind with other atoms and molecules. The announcement of abundant O_2 in comet 67P/Churyumov–Gerasimenko by Bieler (Michigan), Altwegg (Bern) and collaborators involving van Dishoeck and Walsh, therefore came as a big surprise.

Comets are thought to contain the most primitive material in our solar system providing a direct link with the disc and interstellar cloud out of which our Solar system formed. The Rosetta mission to comet 67P provides unprecedented information on the composition of the gases pouring from its nucleus due to heating of the ices as the comet approaches the Sun. High-resolution mass spectrometry measurements allowed molecular oxygen (O_2) to be distinguished from other species with the same mass like sulphur (S) and methanol (CH_3OH) for the first time. Its abundance of ~4% with respect to H_2O makes it the fourth most abundant ice species in the comet, after H_2O, CO and CO_2. A similar O_2 abundance has been confirmed for comet Halley in re-analysis of the Giotto data.

The detection was unexpected because O_2 is so chemically reactive. For example, O_2 can combine with hydrogen atoms on cold dust grains to form water, or a free oxygen split from O_2 by ultraviolet radiation can recombine with an O_2 molecule to form ozone (O_3). All of these processes demonstrated to be efficient at low temperatures in the Sackler laboratory in Leiden by a team led by Linnartz.

In spite of the fact that there are only a couple of detections of O_2 in interstellar space, the team concluded that O_2 must be `primordial', i.e., originates in the cloud from which our Solar system formed and incorporated into the comet's ices. Leiden postdoc Taquet, together with Furuya, Walsh and van Dishoeck, investigated various scenarios under which this could happen. One possibility is that the Solar system formed in an unusually warm part of the prenatal cloud, at temperatures of 20--30 K, rather than the commonly assumed 10 K, which limits the conversion of O_2 to water.

This finding is also a 'wake up call' for exoplanets and the search for life since O_2 is the most prominent gas on the biosignature gas list. The cometary discovery suggests that abiotic O_2 could be brought to planetary atmospheres by impacts of icy planetesimals.

These findings have been reported in an ESO/ALMA press release 1549, NOVA press release November 25, 2015, ESO-ALMA press release 1513, and ESA press release October 28 2015.

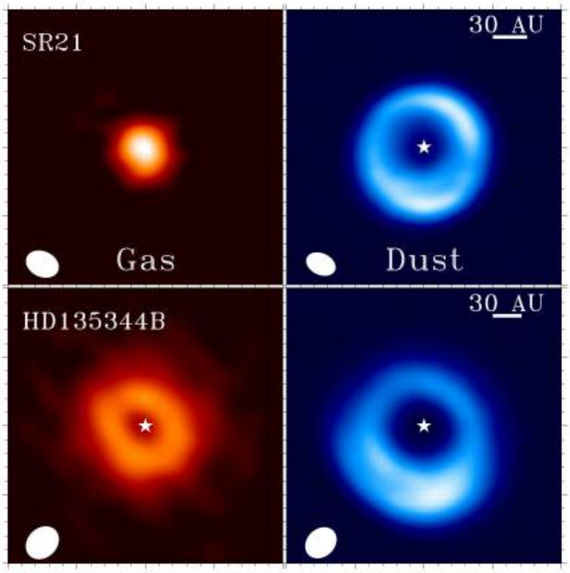
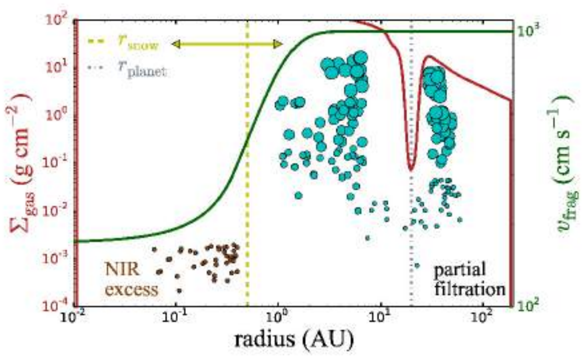


Fig. 1: ALMA observations of the gas (as traced by ^{13}CO, orange) and dust (as traced by millimeter continuum, blue) for two transitional discs. The ALMA beam is indicated by the white ellipse in the lower left corner of each map, whereas the dotted white ellipse indicates the dust cavity radius. Note the presence of gas inside the dust cavities (from: van der Marel et al., A&A 585, A58).



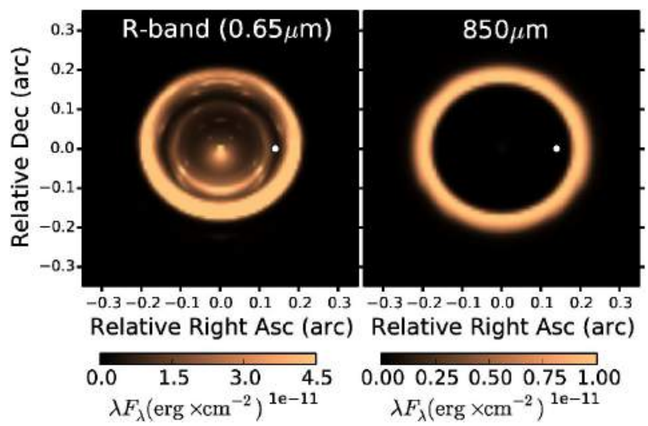


Fig. 2: Left: sketch of particle trapping triggered by a planet located in the outer disk and the effect of the snow line on the dust distribution. Partial filtration of dust from the outer disk and subsequent ice sublimation results in a reservoir of small particles in the inner disk. **Right:** simulation of VLT-SPHERE (R-band) and ALMA millimeter images of the small and large dust particles, respectively (from Pinilla et al., A&A 585, A35).

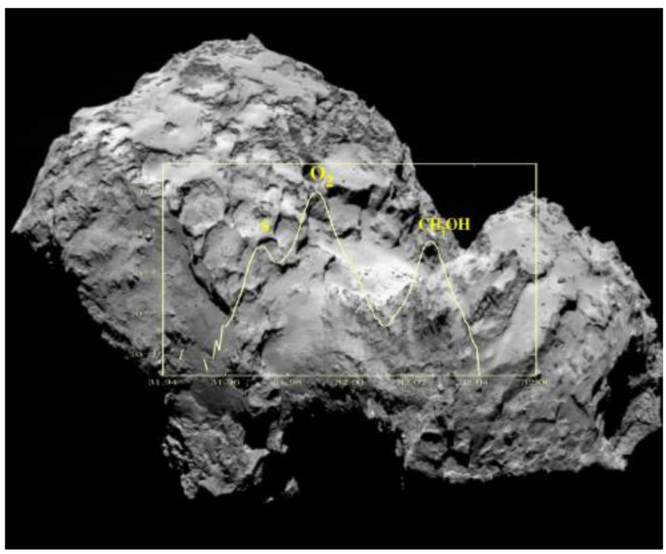
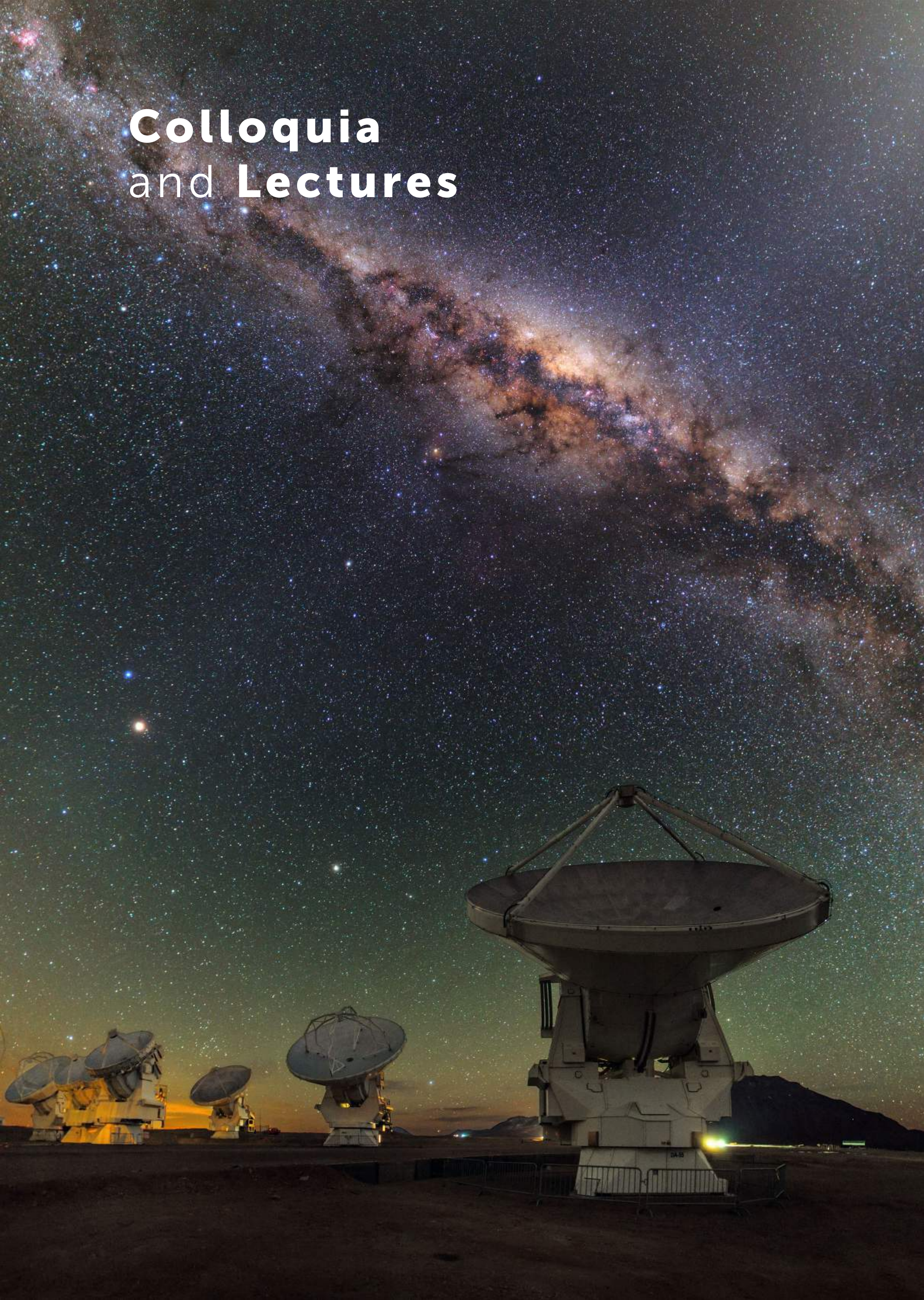


Fig. 3: ROSINA mass spectrometer data superposed on an image of comet 67P/Churyumov-Gerasimenko. The strongest peak at mass 32 is due to O_2, the other peaks are due to sulfur and methanol (Bieler et al., Nature 526, 678). Image credit: ESA Rosetta NAVCAM.

Publications

Over the year 2015, scientists at Leiden Observatory have published a total of 376 articles in international refereed journals. Astronomy & Astrophysics (93 articles; impact factor 4.378), the Astrophysical Journal (95 articles; impact factor 5.909), and the Monthly Notices of the Royal Astronomical Society (121 articles; impact factor 5.521) published together 82% of all papers. The complete list can be found at http://www.strw.leidenuniv.nl/annualreport2015

Colloquia and Lectures



Scientific Colloquia
at Leiden Observatory

15 Jan: Matthias Bartelmann, *Heidelberg University*
Joint reconstruction of galaxy cluster using all observables

5 Feb: Ian Parry, *University of Cambridge*
High contrast direct imaging and spectroscopy of faint close companions with P1640

12 Feb: Jan Cami, *University of Western Ontario*
Cosmic fullerenes

19 Feb: Francois Hammer, *Meudon*
From the first galaxies to the formation of the Hubble Sequence

2 Mar: Jacqueline Faherty, *Carnegie Washington*
The Brown Dwarf Kinematics Project: Meet our Cool Planet-Like Neighbors

5 Mar: Kate Rubin, *Harvard*
Mapping the Cool Baryons: Toward a Physical Picture for Galaxy Evolution

9 Mar: Ruud Visser, *ESO Garching*
From Episodic Accretion to Exoplanet Atmospheres

12 Mar: Sascha Hinkley, *Caltech*
The New Era of Exoplanet Imaging

17 Mar: Jacqueline Hodge, *NRAO*
Revealing the gas-star formation connection over cosmic time

19 Mar: Else Starkenburg, *Leibniz Institute Potsdam*
Galactic Archaeology to its Limits

23 Mar: Kevin Schlaufman, *MIT*
Data-Intensive Astrophysics in the 21st Century: The Oldest Stars and the Origin of Hot Jupiters

26 Mar: Kevin Schawinski, *ETH Zurich*
Galaxy and Black Hole Astrophysics

26 Mar: Craig Heinke, *University of Alberta*
Black Holes in Globular Clusters

31 Mar: Diederik Kruijssen, *MPA*
The multi-scale nature of galactic star formation

9 Apr: Anna Watts, *University of Amsterdam*
The Physics and Forensics of Neutron Star Explosions

23 Apr: Tomas Brage, *Lund University*
Gender issues and implicit bias in (astro)physics

7 May: Chris Raynolds, *University of Maryland*
The physics of the intracluster medium and AGN feedback in galaxy clusters

28 May: Thomas Giesen, *Universitaet Kassel*
High resolution molecular spectroscopy as a tool for interstellar chemistry

4 Jun: Colin Western, *University of Bristol*
PGopher; simulating and fitting spectra

9 Jul: Jack Lissauer, *NASA*
Kepler's Multiple Planet Systems

24 Sep: Alessandro Morbidelli
Planet formation and evolution: origin of the diversity of planetary systems

30 Sep: Bence Kocsis
Liquid crystals of stars and black holes at the centers of galaxies

1 Oct: Zeljko Ivezic
LSST: a color movie of the Universe coming near you!

8 Oct: Ed van den Heuvel
The role of massive binaries in the Universe

15 Oct: Edo Berger
Short-Duration Gamma-Ray Bursts and the Electromagnetic Counterparts of Gravitational Wave Sources

12 Nov: Simon Portegies Zwart
An amuse-ing view towards the evolution of young star clusters

19 Nov: Kathrin Altweg
Living with a comet: highlights from the ROSINA instruments on the European Rosetta mission

26 Nov: Gösta Gahm
Origins of free-floating planetary-mass objects

2 Dec: Ted Bergin
Strategies and Tactics Developed at the University of Michigan to Enhance Diversity and Excellence in the Hiring Process

3 Dec: Adwin Boogert
The Icy Universe

Endowed **Lectures**

The **Oort Lecture**

Prof. Carlos Frenk,
Durham University, UK

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. Carlos Frenk and took place in the Academic Building in Leiden on April 23.

Prof. Frenk is one of the originators of the Cold Dark Matter theory for the origin of galaxies and cosmic structures in the Universe. He has done pioneering work on the development of large computer simulations recreating the growth and evolution of cosmic structures. Currently, he is the director of the Institute for Computational Cosmology in Durham (UK) and Ogden Professor of Fundamental Physics. He is also one of the leading figures in the Virgo Consortium for Cosmological Supercomputer Simulations. In 2014, the British Royal Astronomical Society awarded him the Gold Medal in honour of his outstanding achievements in the field of cosmology.

The title of Prof. Frenk's talk was 'Cosmic origins: everything from nothing'. Cosmology confronts some of the most fundamental questions in the whole of science. How and when did our universe begin? What is it made of? How did galaxies and other structures form? There has been enormous progress in the past few decades towards answering these questions. For example, recent observations have established that our universe contains

an unexpected mix of components: ordinary atoms, exotic dark matter and a new form of energy called dark energy. Gigantic surveys of galaxies reveal how the universe is structured. Large supercomputer simulations recreate the evolution of the universe and provide the means to relate processes occuring near the beginning with observations of the universe today. Prof. Frenk showed that a coherent picture of cosmic evolution, going back to a tiny fraction of a second after the Big Bang, is beginning to emerge. However, fundamental issues, like the identity of the dark matter and the nature of the dark energy, remain unresolved.

The **Sackler Lecture**

Prof. Edwin Bergin,
University of Michigan, USA

The Raymond and Beverly Sackler Lecture 2015 was held on December 1st and given by Professor Edwin Bergin. Prof. Bergin is chair of the Astronomy Department at the University of Michigan in Ann Arbor, USA. He received his PhD in 1995 from the University of Massachusetts. His research focuses on the molecular trail of the origins of habitable worlds. The material that comprises stars, planets, and life on Earth all began the journey as simple molecules. How these molecules formed from atoms, marched towards greater complexity, and ultimately engendered the living world around us is the broad picture of his research. He is a theorist who explores the basics of molecular formation and destruction and also an observer. He has played an important role in a number of observational projects, including as key member of the science team for NASAs Submillimeter Wave Astronomy Satellite (SWAS) and as principal investigator of the HEXOS key program, with over 300 hours of Herschel Space Observatory time, and co-Investigator on two additional Herschel key programs. The Atacama Large Millimeter / submillimeter Array (ALMA) is the most recent addition to his observational repertoire.

Prof. Bergin's talk was entitled 'Probing the beginning of planetary birth in the age of ALMA'. ALMA has begun offering unprecedented spatial resolution and sensitivity within the millimeter and sub-millimeter atmospheric windows. The study of planet birth is one of the key science areas enabled by ALMA due to the ability to resolve both gas and dust emission within the planet formation zones of young gas-rich circumstellar disks. In his talk Prof. Bergin explored the related physics and chemistry of gas-rich disks and emphasized new breakthroughs in our understanding brought about by ALMA in concert with data from the Herschel Space Observatory. In particular he reported on the physical/chemical links in terms of snow-lines and the likely formation of pebbles and possibly planetesimals. Snow-lines represent chemical transitions (ice to vapor) in the disk and have long been posited as favorable sites for planet formation. With ALMA we have now directly and indirectly resolved the carbon monoxide snow-line in several disk systems. Prof. Bergin presented these data and showed compelling new evidence that grain growth is fostered at these locations, perhaps giving rise to the fantastic structure seen in HL Tau. Furthermore the formation of ice-coated pebbles in the increasingly dust rich midplane must deplete the upper layers, and due to radial drift, the outer disk of key ices that carry C, H, O, N. He showed that there is strong evidence for missing volatiles in the disk surfaces layers of the nearest disk system (TW Hya) with an apparent radial gradient in the carbon to oxygen content in the gas and solids. This elemental abundance gradient will likely be imprinted within the atmospheres of forming gas giants and sets constraints on the location of the volatile reservoir needed to form habitable terrestrial worlds.

PhD Colloquia

20 Jan: Dan Caputo
The collapse of clusters of stars

22 Jan: Berenice Pila Díez
The stellar halo of the milky way

27 Jan: Steven Cuylle
Hydrocarbons in interstellar ice analogues

2 Feb: Xiaohu Li
Molecules during Stellar Formation and Death

26 Feb: Sebastiaan Krijt
From grains to planetesimals

16 Apr: Thanja Lamberts
Unraveling the surface formation of regular and deuterated water in space

30 Apr: Irene San Jose Garcia
Paving the path between low- and high-mass star formation with Herschel

19 May: Tiffany Meshkat
Extrasolar Planet Detection Through Spatially Resolved Observations

26 May: Alexander Richings
Non-equilibrium chemistry in simulations of galaxy formation

9 Jun: Monica Turner
The properties of gas around galaxies during the star formation peak of the Universe

18 Jun: Tjarda Boekholt
Chaos in N-body systems: application to triple stars and Halley's comet

3 Sep: Bram Ochsendorf
Tales of Orion: the interplay of gas, dust, and stars in the interstellar medium

8 Sep: Andra Stroe
When Galaxy Clusters Collide: the impact of merger shocks on cluster gas and galaxy evolution

10 Sep: Francisco Salgado
Studies of Dust and Gas in the Interstellar Medium of the Milky Way

15 Sep: Wendy Williams
Facets of radio-loud AGN evolution: a LOFAR surveys perspective

17 Sep: Nienke van der Marel
Mind the gap: gas and dust in planet-forming disks

27 Oct: Marco Velliscig
Probing the darkness: The link between baryons and dark matter

29 Oct: Carmen Martinez
The evolution of the Sun's birth cluster and the search for the solar siblings with Gaia

10 Dec: Carl Shneider
Reconstructing Magnetic Fields of Spiral Galaxies from Radiopolarimetric Observations

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 practicals. In addition to astronomy courses, the programme consists in the first year 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) 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. The Observatory has a strongly international flavour, with close ties with other astronomy institutes in Europe and the U.S. Many students, postdocs and staff come from abroad, and the institute hosts regular visitors from all over the world. 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. **The MSc programme in Astronomy offered six specialisations:**

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

Student Numbers

Student numbers, which have been increasing since several years, continue to rise. In 2015, 64 freshmen started their studies in the Astronomy BSc. Of this number, 12 (19%) were women, and 31 (48%) pursued a combined astronomy/physics or astronomy/mathematics/computer science degree. The Observatory registered a total number of 144 BSc students at the end of the year, of which 73 (51%) aimed at a combined astronomy/physics degree or astronomy/mathematics degree; 28% of all BSc students is female. There were 53 MSc students, including 11 (20%) women and 18 (33%) of foreign nationality.

Organisation

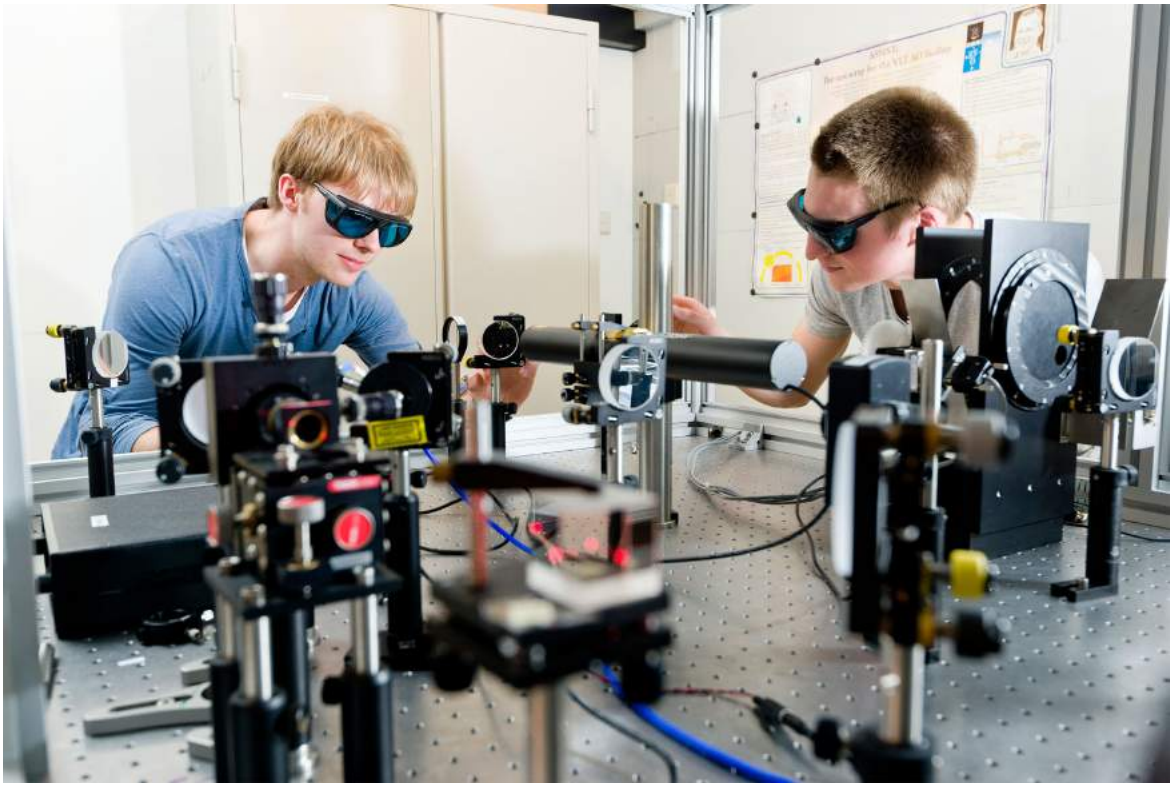
The entire teaching program is organized and supported by the Education Office Astronomy, which deals with all aspects of the curriculum, including organization, student support (by a dedicated Student Advisor), outreach and internationalization.

Pen continued as the education coordinator taking care of the daily running of tasks. Kuijken (1st year students) and Franx (2nd and 3rd year students) continued as study advisers.

Schaye continued as MSc study adviser. All student advisory tasks were taken over by Wouter Schrier, our new dedicated student advisor in May 2015. In addition to counseling by the student adviser, incoming students were assigned to small groups meeting at regular intervals with a staff mentor (Snellen, Hogerheijde, Schaye and Portegies Zwart) 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 & Instrumentation stream is now taught fully by Leiden staff. This has resulted in a number of new courses in the MSc programme. Jose Visser was appointed to specifically support the PR for this track. 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 Netherlands university requires a recommendation by the 'Admissions committee' (Toelatingscommissie) chaired by Portegies Zwart and having Schaye and Kenworthy as members.



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

Courses taught by Observatory staff:

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	E. Rossi
Stars	4	H. Röttgering
Stars and Cosmology	4	M. Franx
Astronomy lab 2	4	J. Brinchmann
Astronomical Observational techniques	5	C. Keller
Radiative processes	5	E. Rossi
Bachelor research project	5-6	K. Kuijken

MSc Courses

Title	Lecturer
Compact Objects and Accretion	Rossi
Data Bases and Data Mining in Astronomy	Brinchmann
High Contrast Imaging	Kenworthy
Observational Cosmology	Bouwens
Origin and Evolution of the Universe	Hoekstra
Optics and Instruments	Keller, Kenworthy and Van Exter
Project Management for Scientists	Keller
Astrochemistry	Van Dishoeck
Astronomy from Space	Fridlund
Computational Astrophysics	Portegies Zwart
Large Scale Structure and Galaxy Formation	Schaye
Detection of Light a + a/b	Brandl
Star and Planet Formation	Van Dishoeck
Stellar Structure and Evolution	Tielens
Science and the public: contemporary and historical perspectives	Van Lunteren

Degrees **awarded** in **2015**

Bachelor's Degrees

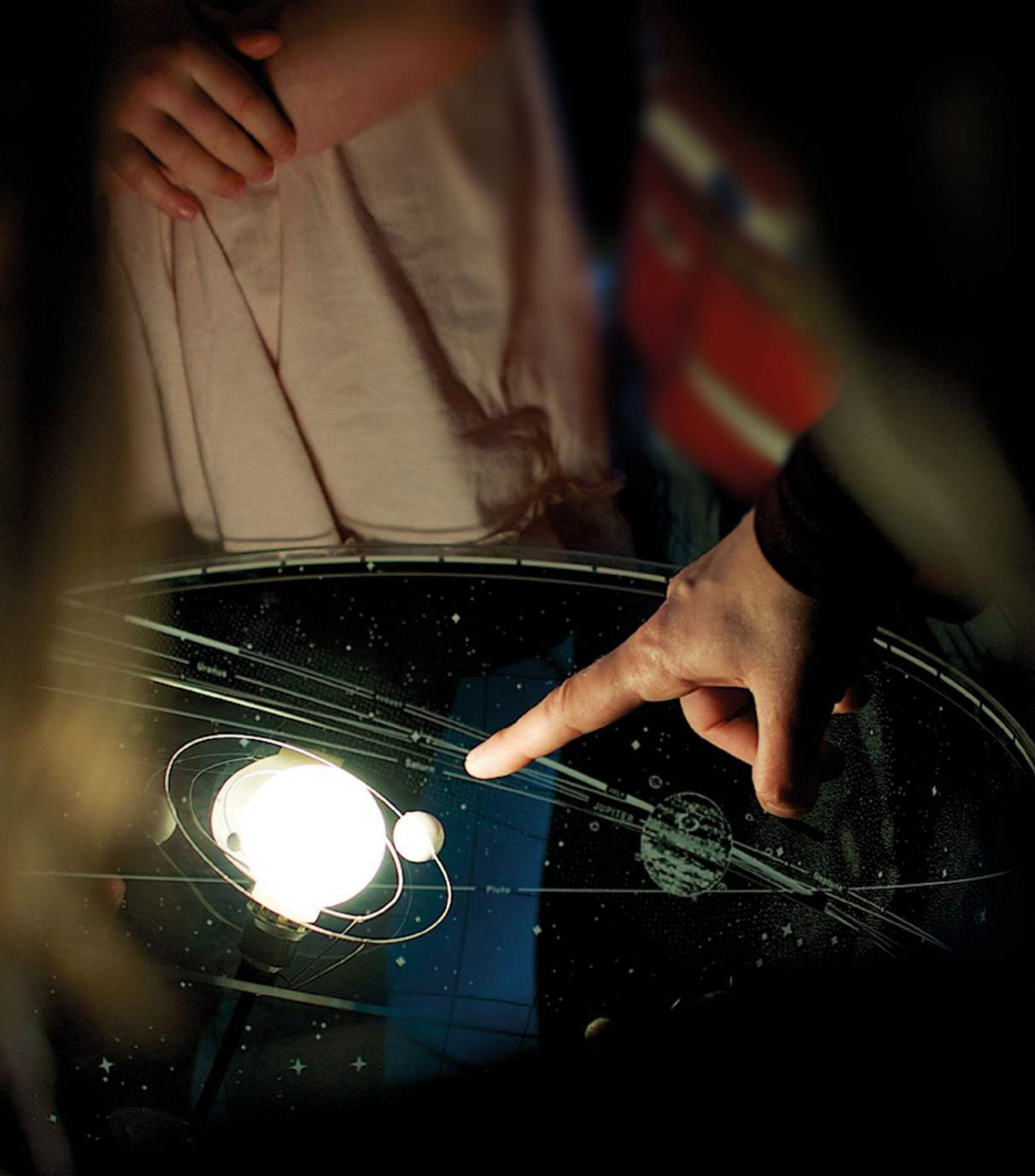
A total of **17 students** obtained their **Bachelor's degree**:

Name	Date	Present Position
Hiddo Algera	31-08-15	MSc Astronomy, Leiden
Ewout Beukers	31-08-15	MSc Applied Physics, TU Delft
Steven Bos	31-08-15	MSc Astronomy, Leiden
Olivier Burggraaff	31-08-15	MSc Astronomy, Leiden
Louis Cheung	31-08-15	MSc Astronomy, Leiden
Jurrien Huisman	31-08-15	MSc Astronomy, Leiden
Hans Klein Woud	31-08-15	MSc Astronomy, Leiden
Vincent Post	31-08-15	MSc Physics, Leiden
Queeny van der Spek	31-08-15	Board member of an Association, afterwards MSc Physics, Leiden
Dieuwertje van der Vlugt	31-08-15	MSc Astronomy, Leiden
Lieke van Son	31-08-15	Travelling, per 1 feb 16 MSc Astronomy, Leiden
Isabel van Vledder	31-08-15	MSc Astronomy, Leiden
Bert Visscher	31-08-15	MSc Physics, Leiden
Elger Vlieg	31-08-15	MSc Physics, Leiden
Mel Voet	31-08-15	MSc Astronomy, Leiden
Bas Zoutendijk	31-08-15	MSc Astronomy, Leiden
Stefano Metafuni	31-08-15	Job searching

Master's degrees

The following **19 students** were **awarded Master's degrees** in **2015**:

Name	Date	Present Position
Arthur Vromans	29-05-15	PhD at Centre for ASA, TU Eindhoven
Sjoerd Cornellisen	31-08-15	Business Analist at DSW Zorgverzekeraar
Chris Lemmens	24-12-15	Capgemini Consulting management consulting
Josha van Houdt	24-12-15	PhD at Heidelberg University
Roman Tatch	30-06-15	Junior.NET Developer, IT Trainee at Rabobank ICT
Julia Heuritsch	31-07-15	NPoC at Space Generation Advisory Council
Shourya Khanna	31-07-15	PhD at University of Sydney, Australia
Mark Kuiack	31-08-15	PhD at Anton Pannekoek Institute, Amsterdam
Luis Quiroga Nunez	31-07-15	PhD at Leiden Observatory in Leiden
Joshua Albert	31-07-15	PhD at Leiden Observatory in Leiden
Merel van 't Hoff	30-06-15	PhD at Leiden Observatory in Leiden
Andrej Dvornik	31-07-15	PhD at Leiden Observatory in Leiden
Arthur Bosman	31-07-15	PhD at Leiden Observatory in Leiden
Sebastiaan Haffert	31-08-15	PhD at Leiden Observatory in Leiden
Sierk van Terwisga	31-08-15	PhD at Leiden Observatory in Leiden
Ronniy Joseph	31-08-15	Programme Coordinator LIACS Leiden University
Keira Brooks	24-12-15	Research and Instrumentation Analyst at STS Institute, Baltimore
Nicholas Rassapu	31-08-15	Risk Model Validator Capital and ALM at Rabobank
Nicola Kroon	31-08-15	Software Developer IT company BUNQ



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.

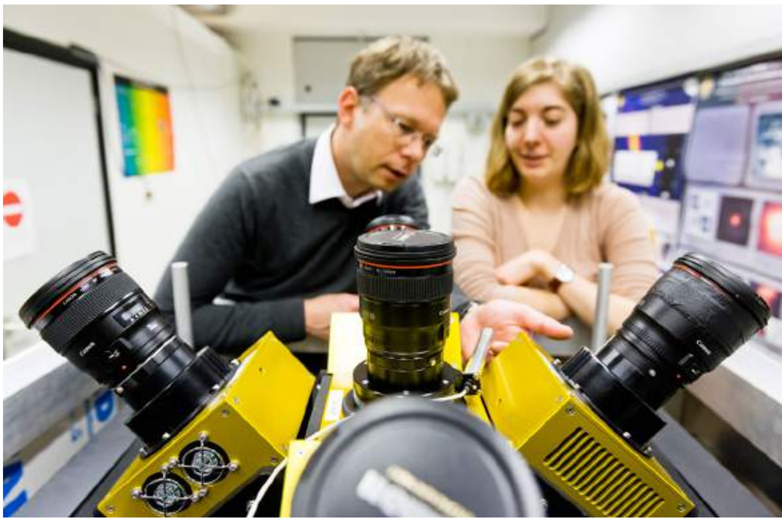
After successfully completing the programme participants have been awarded with a certificate from the University of Leiden. High-school students are allowed to use this project as part of their final exams.

Contact.**VWO**

Contact.VWO (Contact-punt-VWO) is the liaison between pre-university high schools 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 feeded:

- **Teacher meetings:** These meeting 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 sixty participants on average.
- **Teachers seminar astronomy:** Following the same format, we organize a teacher's seminar to support the astronomy part of the science curriculum (NLT). This seminar is organized once a year (October) and is attended by about twenty-five teachers.

- **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 (40 teachers, 120 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 schools 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.
- **Posters:** Twice a year 250 schools in our region receive two posters. The posters highlight a research novelty and announce upcoming events .

International **Education** and **Public Outreach** projects

Leiden Observatory regards Education and Outreach (EPO) as a core part of its mission. The Department has instigated several international astronomy-based EPO projects and has been successful in raising substantial external funds to support them (see Table 1).

Universe Awareness (UNAWE)
(Miley, Russo) ~ 3.5 M Euro.

The Universe Awareness (www.unawe.org) project continued during 2015, albeit with ad-hoc funding. UNAWE uses inspirational aspects of astronomy to target children aged 4 to 10, particularly those from disadvantaged backgrounds. The goals are twofold – to use the excitement of astronomy to interest 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 system is forming. Ingredients of UNAWE include teacher training, production of professional educational materials and an multidisciplinary network.

UNAWE is now active in more than 60 countries, is highly visible and has resulted in considerable publicity at both national and international levels. UNAWE was started with the help of a KNAW Academy professorship and seed funding of 325,00 Euro given personally by Minister van der Hoeven of Education, Culture and Science. UNAWE was a cornerstone project of the UN-ratified International Year of Astronomy IYA2009 and an important part of the IAU Strategic Plan 2010 – 2020 “Astronomy for Development”. Subsequently the Space Directorate of the European Commission (Industry and Enterprise) awarded 2 M Euro to the Faculty for the implementation of UNAWE in 5 European countries and South Africa from 2011 - 2014. UNAWE spinoffs include astroEDU – a prize-winning repository of resources for pre-university teachers endorsed by the International Astronomical Union, Space Scoop – an astronomy news service for children and teachers and the “Universe in a Box” kit of which > 1000 examples have been distributed globally through a successful crowd funding campaign, organized in 2014. UNAWE and its spin-offs have won several international prizes and have been featured in several articles in the international press. Three new partner countries joined UNAWE in 2015. During 2015 there was a large influx of refugees into the Netherlands and into Europe. Initiatives were developed to use UNAWE as a tool for stimulating the integration of refugees and funds for these UNAWE-based refugee projects are being sought.

Fig. 1: A Universe Awareness activity using the prize-winning “Universe in a box” educational kit at the Charles Wraith Primary School, Zimbabwe in March 2015

EU Space Awareness
(Miley, Russo, Brinchmann) 2M Euro.

During 2015 Leiden Observatory began leading a new project, called EU Space Awareness (EUSPACE-AWE). EUSPACE-AWE (http://www.space-awareness.org/en/) was one of the two of 16 submitted proposals to be funded by the EC Space Directorate in response to a Horizon 2020 Call. Leiden Observatory is the initiator, lead-partner and coordinator of the project that is being implemented during 2015 – 2018. EU Space Awareness is designed to use the excitement of space to attract young people into science and technology and stimulate European and global citizenship. The project is showing teenagers career opportunities offered by space science and engineering and inspiring primary-school children when their curiosity is high, their value systems are being formed and seeds of future aspirations are being sown. Although components of Universe Awareness are included in EUSPACE-AWE, the scope of Space Awareness was extended to target young people between ages 4 and 18 in order to comply with the work programme of the Call. Leiden is coordinating the project that includes 9 full partners institutes and 15 additional "dissemination nodes".

EUSPACE-AWE activities include: 1. Acquainting young people with topical cutting-edge research and "role-model" engineers, 2. Demonstrating to teachers the power of space as a motivational tool and the opportunities offered by space careers, and 3. Providing a repository of innovative peer-reviewed educational resources, including toolkits highlighting seductive aspects of ESA's Galileo and Copernicus missions. Attention is being paid to stimulating interest amongst girls and ethnic minorities and reaching children in underprivileged communities, where most talent is wasted. A unique tool being developed under the auspices of this project is an Islamic Heritage toolbox that illustrates how scientists in Islamic countries influenced the development of modern space science.

ISPEX (Snik, Keller)
~ 0.5M Euro

The ISPEX SCS project (http://ispex-eu.org), pioneered by the Leiden astronomy department is a citizen science project that exploits a spectropolarimeter developed for astronomy together with an I-phone add-on to map dust particles in the atmosphere. Using 150,000 Euro, awarded as part of the Academische Jaarprijs 2012, the ISPEX consortium carried out a highly successful campaign to map the atmospheric dust content throughout the Netherlands. About 6000 members of the public, mainly young people participated and a paper with the results was published in Geophysical Research Letters. The project received considerable attention in the media. The Leiden department is presently coordinating a successor project in which a similar campaign will be rolled out in 7 – 10 cities across Europe under the auspices of a Horizon 2020 International Year of Light project.

Leiden Citizen Science Lab – CSLab
(Keller, Snik, Russo, Hendriks) 30k Euro

The European Space Agency (ESA) has accepted a proposal to provide 30,000 Euro as seed funding for a Citizen Science Lab (CSLab) at Leiden in close collaboration with ESA. The CSLab will serve as the incubator and central hub for citizen science projects involving ESA environmental data and Earth observations. It builds on the world-class citizen science, outreach and education expertise at Leiden University, and leadership of the International Year of Astronomy, Universe Awareness, iSPEX and IAU astroEDU. During Phase 1, an inventory will be made of opportunities for multidisciplinary citizen science projects with an ESA component and a strategic study to investigate the involvement of essential stakeholders and to obtain sustainable funding.

Teaching Enquiry with Mysteries Incorporated (TEMI)
(Russo, Miley) 207K Euro

TEMI (http://www.teachingmysteries.eu) is a teacher training project being coordinated from Queen Mary University London to help improve science and mathematics teaching practice across Europe by giving teachers new skills to engage with their students, exciting new resources and the extended support needed to effectively introduce enquiry based learning into their classrooms. Innovative training programmes called 'enquiry labs' are being implemented across Europe, working with teacher training institutions and teacher networks. These will be based around the core scientific concepts and emotionally engaging activity of solving mysteries, i.e. exploring the unknown. The main role of Leiden Observatory in the project has been to deliver the TEMI teacher training programme in the Netherlands and promote its outcome to policy-makers, local teacher networks and other professional bodies.

Europlanet
(Russo, Miley), 37k Euro

Europlanet (http://www.europlanet-2020-ri.eu) links laboratories active in planetary research in Europe and around the world. Since 2005, Europlanet has provided Europe's planetary science community with a platform to exchange ideas and personnel, share research tools, data and facilities, define key science goals for the future, and engage stakeholders, policy makers and European citizens with planetary science. Under the Horizon 2020 project, Leiden Observatory has developed media training material for researchers.

The IAU Astronomy for Development Programme **(Miley, Russo)**

Leiden Observatory has played a key role in the initiation and implementation of the IAU Astronomy for Development (AfD) programme and Universe Awareness is an integral part of this programme. As IAU Vice President, Miley was architect of the IAU Strategic Plan Astronomy for Development 2010 – 2020 (http://www.iau.org/static/education/strategicplan_2010-2020.pdf), helped set up the IAU Office of Astronomy for Development (OAD) in 2011 and was Chair/ Vice Chair of its first steering committee from 2011 to 2015.

The IAU plan exploits the unique scientific, technological, cultural and inspirational aspects of astronomy to stimulate technological and human capacity building throughout the world. The IAU Office of Astronomy for Development (http://www.astro4dev.org) is a joint venture between the IAU and the South African National Research Foundation. Following a blueprint outlined in the Plan, the OAD established nine regional offices in Africa, Asia and South America and three "task forces" that focus on universities, schools and the general public. Russo is Chair of the OAD Task Force on Schools and Children.

Project	Main Target group	Geographical scope	External Funds (€)	Funder
Universe Awareness	Children aged 4–10 Teachers (Focus on disadvantaged communities)	Global and NL	~100k	KNAW Academie-hglr
			375k	Minister OC&W
			~600k	Platform Beta-techniek (VTB+)
			2M	EC Space Directorate (FP7)
			20k	Gratama-fonds/LUF
			15k	NWO Creative
			17k	Crowd funding
			23k	Donation via ESA
EU Space Awareness	Youth aged 4–18 Teachers	Global mainly Europe	2M	EC Space Directorate (H2020)
ISPEX	Members of public (Citizen Science)	Netherlands	100k	Academische Jaarprijs
			~ 50k	Sponsoring etc.
		Europe	~ 200k	EC (H2020 IYL)
Leiden Citizen Science Lab	Members of public	Global mainly Europe	30k	ESA
Teaching Enquiry with Mysteries Incorporated (TEMI)	Teachers	Europe	207k	EC (FP7) Coordinator QMC
Europlanet	Researchers and members of the public	Europe	45k	EC(H2020) Coordinator Open University
(IAU Astronomy for Development Programme)[1]	Universities and research Schools and children Public	Global		International Astronomical Union
				South African National Research Foundation

Table 1. Major international EPO Projects instigated or partnered by Leiden Observatory.

Visitor Centre in the **historic Observatory** building

Since 2012, the historic observatory building hosts a visitor centre, aiming to convey the beauty of the universe and the rich history of Leiden astronomy. Access is via the university botanic gardens on Wednesdays and in the weekend. Leiden undergraduate students play a central role in the operation of the visitor centre and the astronomical instrumentation on the roof, with guided tours through the visitor centre and along the historic telescopes. In addition, the building is open at special occasions, such as the national stargazing nights (Sterrenkijkdagen), the national Museum Night (Museumnacht), the Night of Art and Knowledge (Nacht van kunst en kennis) en de annual Observatory open days. In total, the visitor centre attracted 12000 guests, and 120 tours were conducted of the historic telescopes - all organised by the student society L.A.D. F. Kaiser.

Special exhibitions

During the second half of the year there were two exhibitions in the visitor centre. The first was the exhibition of the Akademieprijs Astronomie en Kunst (the Academy Prize Astronomy & Art). The prize (5000 euro) was provided by prof. Ewine van Dishoeck. The winning artwork and the works of the other nominees were on display in the visitor centre. The first prize went to artist Ronald Schimmel with his work “Zwarte Zon” (Black Sun). The second exhibition about the Sun by Els Botman was installed in the Old Observatory in October. The artwork shows different images of the Sun.

The year had a flying start with the crowdfunding activities for the new heliostat. The heliostat projects an image of the sun on the wall in the basement of the observatory where the visitor centre is placed. Building of the telescope started immediately after the 20 000 euros were raised in order to have a working telescope ready for the solar eclipse on the 20th of March.

Special events

During spring, the observatory was opened for three big events. The first were the Sterrenkijkdagen, in March organised by the Werkgroep Leidse Sterrewacht with help of the Leidse Weer en Sterrenkundige Kring (LWSK), Jeugdwerkgroep Leiden (JWG) and the astronomy students of L.A.D. F. Kaiser. With more than 700 visitors, this was a great success. There were many activities in the Observatory: the mobile planetarium was set up, there were tours of the domes, and special activities for children.

On the 30th of May, the observatory opened its doors for the Museumnacht, organised by the Leiden student association Quintus and L.A.D. F. Kaiser. Brecht Simon of Kaiser and Quintus put together a wonderful program with a stand where people could ask an astronomer anything about astronomy (Benne Holwerda and Huub Röttgering), a nice animation about the history of the Leiden Observatory by Maria de Fraaije, a string orchestra and RINO installed a human levitator.

On the 21st of June the observatory was open to the public again. The Hortus organised their Midzomernacht (Midsummer night) festival. Many visitors came to the observatory to take a look through the telescopes in the domes and enjoy this long evening in the most beautiful garden in Leiden. The Huygens telescope was set up in the garden especially for the event.

The autumn program started in September with the Nacht van Kunst en Kennis. Especially for this event the large dome of the Astro

Photographic telescope was transformed in a work of art called “Huygens chamber” by Beatrix Salcher, showing the interplay of light and glasses with fringe patterns inspired by the work of Christiaan Huygens.

The annual Open Dag (Open Day) of the observatory was organised this year by Dr. Henk Hoekstra. Many Sterrewachters came to help during the day as well as the students from Kaiser, the JWG, UNAWE and the WLS. The Open Day was visited by 800 people. The night before the Open Day, the Observatory was open for the Nacht van de Nacht (Night of the Night), allowing to let people observe with the telescope and to generate attention for the importance of a dark night.

TV and film at the historic observatory building

During the year, the observatory provided the stage for the documentary Einstein’s light by Nickolas Barris. This documentary focused on the friendship between Lorentz and Einstein. It premiered on November 2nd in the Leiden Trianon theater and showed beautiful images of the Old Observatory made with a drone. It also featured ALMA and an interview with prof. Dr. Ewine van Dishoeck.

The famous Dutch informative television program for children Het Klokhuis, also paid a visit to the observatory. The scenes were filmed on the roof and in the domes, where topics such as life on Mars, space telescopes and humans in space were introduced.

Arguably the highpoint of the year was that the old Observatory hosted the live national television program, Heel Nederland Kijkt Sterren, the Dutch version of the very popular BBC show Stargazing Live. About 860 000 people tuned in to learn about astronomy.

A group of students of the observatory and hobby astronomers gathered on the roof to gaze at the stars. The beautiful ambiance of the Old Observatory fully lit by spot lights especially for the occasion, made the bad weather almost invisible. The whole program was a joy of recognition. Many familiar faces from the observatory passed in front of the camera. There were interviews with Ewine van Dishoeck, David Baneke and the students on the roof.

The new **heliostat**

For many years there have been plans for a solar telescope at the old observatory, a heliostat that can project the Sun on a wall for public demonstrations and to allow visitors to explore the surface of the Sun during the day. In late 2014 visitors center committee has decided that this telescope should finally be built and started planning the design, location and funding. It was decided to use an old chimney, through which the Sun can be directed from the roof to the basement, 13 meters below, resulting in a 80 cm solar image. The telescope was funded via a very successful crowd funding exercise (€20,000.). This event, coined ‘Breng de Zon naar Leiden’ (bring the Sun to Leiden) collected the necessary funds within 4 weeks.

The instrument builders from the Leidse Instrumentmakers School, amateur astronomers from the Werkgroep Leidse Sterrewacht and instrumentalists from Leiden Observatory started to build the instrument, aiming to have first light after roughly a month on the 20th of March - the date of a partial Solar eclipse during which many visitors were expected. The bare bone telescope, without a dome or protective casings but capable of making solar projection, was indeed finished at the date of the eclipse, but the event was completely clouded out. This did not stop roughly 1000 people to visit the observatory that day, which featured on the national TV news.

The heliostat was finished somewhat later, with a brand new dome being put on the roof of the observatory a few weeks later, (The first new dome in 68 years!) and the rest being finished throughout the Summer. Ever since then the telescope is a part of the new permanent exhibition of the Old Observatory visitors centre. This fantastic project was only

possible because of the great efforts put into it by the heliostat team. Staff and students from the observatory, amateur astronomers from the werkgroep Leidse Sterrewacht, instrument makers and students from the Leidse Instrumentmakers school, vastgoed and gebouwbeheer, in particular Kees Moddemeijer, Donald van de Burg, Cloeck Beekhuis, Felix Bettonvil, Jaap de Bree, Roel Brouwer, Johan van Kuilenburg, Ivo Labbe, Alexander Pietrow, Frak van Rijn, Gerard Smit, Frans Snik, Remko Stuik and Sascha Zeegers

Social Networking

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

The Leidsch Astronomisch Dispuut F. 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 integrate astronomy students into the Leiden Sterrewacht by organising social activities. In addition, Kaiser facilitates practical observing sessions using the historic telescopes of the old observatory, and is extremely active with outreach events.

Social events

Kaiser is best known for its annual football tournament, which includes teams from both observatory staff and students, but also organises 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 setting up radio communication with other parts of the globe by bouncing signals of the Moon.

Kaiser has several sub-committees, such as the Observing Committee which organises observations sessions with the historic telescopes, and the Historical Committee which studies the institute archives and interviews older Astronomers to find out more information about the history of the observatory.

Outreach

L.A.D. 'F. Kaiser' trains the students that perform tours through the historic observatory. These tour guides, along with other members, also form the backbone of the organisation of mayor public events at the observatory, such as during the 2015 Solar- and Lunar Eclipses,the annual Nationale Sterrenkijkdagen (National Stargazing Nights), and the Nacht van Kunst en Kennis (Night of Art and Knowledge).

Kaiser also organised the second edition of their annual public lecture series, de Kaiser Lente Lezingen, also at the old observatory. It featured Huib Zuidervaart, Joe Zender, Vincent Icke and Kees de Jager, and was completely sold out.

The Kaiser board in 2015 consists of Mark Knigge (praeses/chairman), Dennis Vaendel (quaestor/treasurer), Dominique Petit dit de la Roche (assessor Old Observatory) and Kimberly Emig (assessor outreach).

Alumni **Association**

Studying or working at Leiden Observatory is an unforgettable experience to many, with on the one hand the exciting discoveries of 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. Membership is open to all Leiden Observatory alumni and staff.

Social events

Prior to the Oort Lecture by Prof. Carlos Frenk on April 10, VO-S organised, as every year, a social gathering in a Leiden Cafe. Early July, some 20 alumni convened at the Old Observatory for an update on present research in astronomy. Scientific Director Huub Röttgering shared an overview of the exciting progress made at the Sterrewacht in research of exo-planets, astro-chemistry and the early universe. Anthony Brown gave a brief insight into the GAIA program, that will basically map a major part of our galaxy at an unprecedented scale and precision. Afterwards, the VO-S members joined the Observatory barbeque event in front of the Oort building, and enjoyed this great opportunity to renew ties with Observatory students and staff.

Our annual meeting was held on at the Berne Abbey at Heeswijk, hosted by alumnus Frank van Roermund, who joined the abbey after a career in aero industry. An audience of more than 30 VO-S members enjoyed his presentation on his journey into religious life and joined in a tour afterwards through the abbey church and buildings. The VO-S Committee was happy to add Leonie Snijders to her ranks. She will focus on strengthening our network ties with young alumni.

The Kaiser Price was presented to Alex Pietrow, a master student at Leiden who played a key role as volunteer and coordinator in the establishment of a solar telescope at the Old Observatory at Leiden. The annual meeting was concluded by the tasting of the brand new 'Berne abbey beer', which proved to be a huge success.

Career path guidance for current students

Also, further steps were set in providing mentoring for students who consider a career outside astronomy. In April and May VO-S chairman Niels van Weeren held 2 talks at the Sterrewacht on 'working life as an alumnus', for audiences of bachelor and master students and post-graduates. These talks aimed at sharing experiences on a career outside astronomy and raising awareness on the network value of the alumni association.

After its renewal in 2014, the VO-S website has been hosted and facilitated by the Faculty of Science. This has proven to be a major improvement in communicating with our audience. We thank Poppy Savenije for her ongoing efforts in keeping our website updated and preparing our news letters twice a year.

For contact and membership of our alumni association:

visit our website: www.vo-s.nl
send an email to: vo-s@strw.leidenuniv.nl

VO-S Committee: Yuen Ng, Erwin van Soest, Leonie Snijders, Niels van Weeren (chair), Gerben Zwart and Anthony Brown (liaison).

Organization

Observatory **Staff**

Full professors

Dhr Prof.dr. B.R. Brandl

Mw Prof.dr. E.F. van Dishoeck

Dhr Prof.dr. M. Franx

Dhr Prof.dr. C.U. Keller

Dhr Prof.dr. K.H. Kuijken

Dhr Prof.dr. H.V.J. Linnartz

Dhr Prof.dr. F.H. van Lunteren
(0.5 fte UL , Teyler's hoogleraar / 0.3 fte VU)

Dhr Prof.dr. S.F. Portegies Zwart

Dhr Prof.dr. H.J.A. Rottgering

Dhr Prof.dr. J. Schaye

Dhr Prof.dr. I.A.G. Snellen

Dhr Prof.dr. A.G.G.M. Tielens

Dhr Prof.dr. P.P. v.d. Werf

Dhr Prof.dr. P.T. de Zeeuw

Affiliate professors

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

Dhr Prof.dr. N.J. Doelman
(J.H. Oortfonds)

Mw Prof.dr. P. Ehrenfreund
(0.0 fte)

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

Dhr Prof.dr. M.A. Garrett
(Director ASTRON)

Dhr Prof.dr. J.S. Kaastra
(Senior Scientist SRON)

Dhr Dr. H.J. van Langevelde
(Director ive, Dwingeloo)

Asosciate and **Assistant** Professors, **Senior** Researchers

Dhr Dr. R.J. Bouwens

Dhr Dr. J. Brinchmann

Dhr Dr. A.G.A. Brown

Mw Dr. M. Haverkorn van Rijsewijk
(0.0 fte, staff Radboud University Nijmegen)

Mw Dr. J.A. Hodge

Dhr Dr. H. Hoekstra

Dhr Dr. M.R. Hogerheijde

Dhr Dr. M.A. Kenworthy

Dhr Dr. A. Patruno

Mw Dr. E.M. Rossi

Dhr Dr. R. Stuik

Dhr Dr. R.P.J. Tilanus
0.0 fte (NWO)

Dhr Dr. I.F.L. Labbé

Emeriti

Dhr Dr. A.M. van Genderen

Dhr Prof.dr. H.J. Habing

Dhr Prof.dr. V. Icke

Dhr Prof.dr. F.P. Israel

Dhr Dr. W.J. Jaffe

Dhr Dr. J. Lub

Dhr Prof.dr. G.K. Miley

Dhr Drs. R.S. le Poole

Postdocs / project **personnel** / longterm **visiting** Scientists

Dhr Dr. H. Alvaro Galue

Dhr Dr. M.A. Bilicki

Dhr Dr. J.B. Bossa

Dhr Dr. M. Cacciato

Mw Dr. A. Candian

Mw Dr. Y.A. Contreras Morales

Mw Dr. G. Costigan

Dhr Dr. G.A. Cruz Diaz

Mw Dr. C.R. D'Angelo

Dhr Dr. M. De Lima Leal Ferreira
Guest - Externally funded

Dhr Dr. J.M.F. Donnert

Dhr Dr. K.J. Duncan

Dhr Ir. A.K. van Elteren
Guest

Dhr Dr. M.B. Eriksen

Dhr Dr. G. Fedoseev

Dhr Dr. T.A. Fernandes Gomes Da Costa

Dhr Dr. M. Fumagalli

Dhr Dr. F. de Gasperin

Dhr Dr. C. Ginski

Mw Dr. I.R. Guerra Aleman

Dhr Dr. R.H. Hammerschlag
Guest

Dhr Dr. G. van Harten

Dhr Dr. A.N. Heays

Dhr Mr. E.M. Helmich

Mw E.C.J. Hendriks MSc

Dhr Dr. B.W. Holwerda

Dhr P.W. Hoogendoorn
Guest

Dhr Dr. A.P. Hypki

Dhr Dr.ing. H.T. Intema

Mw N. Irisarri Mendez MSc

Mw Dr. L. Jilkova

Mw Dr. S. Jin

Dhr Dr. J.T.A. de Jong

Dhr Dr. M. Kama

Mw Dr. J.K. Katgert-Merkelijn
Guest

Dhr Dr. M. Kazandjian

Dhr Dr. T.A. van Kempen

Dhr Ing. J.N.M. Kommers

Mw Dr. A. Lesage

Dhr Dr. X. Li

Mw Dr. N. v.d. Marel

Dhr Dr. M.V. Maseda

Dhr Dr. L.T. Maud

Dhr Dr. R. Meijerink

Dhr Dr. J.A. Meisner

Mw Dr. T.R. Meshkat

Dhr Dr. E.P. Monaghan

Dhr Dr. J.C. Mottram

Dhr Dr. J.B.R. Oonk

Dhr Dr. F.I. Pelupessy

Dhr Dr. M.V. Persson

Mw Dr. A. Petrignani

Mw Dr. P.A. Pinilla Ortiz

Mw Dr. S. Plöckinger

Mw Dr. E.E. Rigby

Dhr Dr. K.J. Rosdahl

Dhr Dr. F.J. Salgado Cambiazo

Mw Dr. I. San Jose Garcia

Mw Dr. E. Schmalzl

Dhr Dr. M. Schmalzl

Dhr Dr. C. Schreiber

Dhr Dr. D.R. Serrano Goncalves Sobral

Dhr Dr. T.W. Shimwell

Dhr Dr. G. Sikkema

Dhr Dr.ir. F. Snik

Dhr Dr. J.F.P. Spronck

Dhr Dr. M. Stefanon

Dhr Dr. I.M. Stewart

Mw Dr. L.A. Straka

Dhr Dr. V.D.F. Taquet

Promovendi

Dhr Dr. J.J. Tobin

Mw Dr. S.G.M. Toonen

Mw Dr. M.C. Toribio Perez

Dhr Dr. M. Velliscig

Dhr Dr. M. Viola

Mw Dr. C. Walsh

Dhr Dr. I. Yoon

Dhr Dr. D. Zhao

Mw A.S. Abdullah MSc

Dhr J. Albert MSc

Mw H.E. Andrews Mancilla MSc

Dhr X. Bacalla MSc

Dhr C.R. Barber MSc

Dhr Dr. T.C.N. Boekholt

Dhr J. de Boer MSc

Mw E.G. Bogelund MSc

Dhr C.A. Bonnerot MSc

Dhr A.D. Bosman MSc

Mw S. v.d. Broek MSc

Mw M.M. Brouwer MSc

Mw G.E. Calistro Rivera MSc

Dhr M.T. Carney MSc

Dhr D.J. Carton MSc

Dhr P. Castellanos Nash MSc

Dhr P. Cazzoletti MSc
Guest

Dhr K. Chuang MSc

Dhr B.J.F. Clauwens MSc
Guest, LION/STRW

Mw V. Cordeiro de Sousa Santos MSc
Externally funded

Mw L. Di Gesu MSc
Guest

Dhr E. Di Gloria MSc

Mw K.D. Doney MSc

Mw M.N. Drozdovskaya MSc

Dhr A. Dvornik MSc

Dhr C. Eistrup MSc

Mw K.L. Emig MSc

Dhr J. Franse MSc
Guest, LION/STRW

Dhr Dr. M. Fumagalli

Dhr C. Georgiou MSc

Mw C. Giese MSc

Dhr S.Y. Haffert MSc

Dhr A.S. Hamers MSc

Mw S. Heikamp MSc

Dhr E. v.d. Helm MSc

Dhr R.T.L. Herbonnet MSc

Mw A.R. Hill MSc

Dhr N.D. Hoang MSc

Dhr H.J. Hoeijmakers MSc

Mw M.L.R. van t Hoff MSc

Dhr V. Kofman MSc

Dhr F. Köhlinger MSc

Mw V. Korol MSc

Dhr Dr. S. Krijt

Dhr C.C. Lam MSc

Mw Dr. A.L.M. Lamberts

Dhr Dr. X. Li

Dhr N.F.W. Ligterink MSc

Dhr N. Lopez Gonzaga MSc

Dhr J.C. Mackie MSc

Dhr T. Marchetti MSc

Mw Dr. N. v.d. Marel

Mw C.A. Martinez Barbosa MSc

Dhr J.J.A. Matthee MSc

Dhr A.P. Mechev MSc

Dhr F.D.M. Mernier MSc

Mw Dr. T.R. Meshkat

Mw A. Miotello MSc

Mw L.K. Morabito MSc

Mw A.B. Nielsen MSc

Dhr Dr. B.B. Ochsendorf

Dhr G.P.P.L. Otten MSc

Mw M. Paalvast MSc

Dhr D.M. Paardekooper MSc

Mw C.H.M. Pabst MSc

Mw Dr. B. Pila Diez

Dhr L.H. Quiroga Nunez MSc

Dhr E.F. Retana Montenegro MSc

Dhr Dr. A.J. Richings

Dhr A.R. Ridden - Harper MSc

Dhr A.J. Rimoldi MSc

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Mw H. Schwarz MSc

Mw M.C. Segers MSc

Dhr Dr. C. Shneider

Dhr C.J. Sifon Andalaft MSc

Mw C.M.S. Straatman MSc

Dhr A.H. Streefland MSc

Mw Dr. A. Stroe

Dhr G.J.J. Talens MSc

Dhr S.E. van Terwisga MSc

Dhr S. Torres Rodriguez MSc
Externally funded

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Mw I. Urdampilleta Aldama MSc
Guest, SRON/STRW

Dhr Dr. M. Velliscig

Mw Y.M. Welling MSc

Dhr M.J. Wilby MSc

Mw Dr. W.L. Williams

Mw E.M. Zari MSc

Mw S.T. Zeegers MSc
Guest, SRON/STRW

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Mw G.A. v.d. Tang
secretary

Mw L. v.d. Veld
secretary

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Education assistant

Mw Drs. A.N.G. Pen-Oosthoek
Education coordinator

Dhr Dr. J. v.d. Sande
Education assistant

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Mw L. v.d. Veld
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Dhr Dr. D.J. Jansen
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Dhr E.J. v.d. Kraan
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Dhr Dr. L. Lenoci
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Dhr A. Vos
Programmer

NOVA office

Dhr Ir. F.C.M. Bettonvil
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Dhr Dr. W.H.W.M. Boland
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Guest

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Dhr Dr. M. Rodenhuis
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International Project Manager

Mw A.K. Romero Branchadell BA
Guest

Mw T.R. Sankatsing Nava MA

Mw A. Savre MSc

Observatory **Committees**

Directorate

H.J.A. Röttgering
(Scientific Director)

P.P. van der Werf
(Director of Education)

E. Gerstel
(Institute Manager)

Management Teams

H.J.A. Röttgering
(General Management)

I.A.G. Snellen
(Outreach)

C. U. Keller
(Instrumentation)

E.R. Deul
(ICT/Housing)

E. Gerstel
(HR, Finances)

P.P. van der Werf
(Education)

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H. Hoekstra

J. Lub

B.Brandl

M. Hogerheijde

F. van Lunteren

J. Brinchmann

V. Icke

G.K. Miley

A.G.A. Brown

F.P. Israel

S. Portegies Zwart

E.R. Deul

W. Jaffe

E. Rossi

D. van Delft

C.U. Keller

H.J.A. Röttgering

E.F. van Dishoeck

K.H. Kuijken

J. Schaye

N. Doelman

M. Kenworthy

I.A.G. Snellen

M. Franx (Chair)

H.J. van Langevelde R. Stuik

M. Garrett

R.S. Le Poole

A.G.G.M. Tielens

M. Haverkorn

H.V.J. Linnartz

P.T. de Zeeuw

J. Hodge

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(Chair)

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E. van der Helm

I. Aleman

H. Hoekstra

C. Lemmens

M. Segers

I. Labbé

A. Vos

K. Doney

J. Spronck

Education Committee **(Opleidingscommissie - OC)**

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C. Keller

L. van Slujis

M. Segers

E. Rossi

D. Kleingeld

M. Janse

Board of **Examiners**

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(Physics)

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A. de Koter
(UvA - External)

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J. Schaye

Mayo Greenberg Prize Committee

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(Chair)

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J. Lub

E.F. van Dishoeck

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MSc Admission Advisory Committee

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S. Portegies Zwart

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S. Portegies Zwart

R. Crain

R. Stuik

Oort Lecture

B. Brandl

Sackler Lecture

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R. Herbonnet

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R. Meijerink

W. Schrier

D. Klaassen

M. Brouwer

S. Mandal

I.A.G. Snellen

C. barber

A.-S. Nielsen

University Committee Memberships

H.J.A. Röttgering

- Leids Kerkhoven-Bosscha Fonds: Secretary/treasurer
- Leids Sterrewacht Fonds: Secretary/treasurer
- Jan Hendrik Oort Fonds: Secretary/treasurer

A. Brown

- Member, Faculteitsraad

E. Deul

- Member of High Performance evaluation team Universiteit Leiden

E. Van Dishoeck

- Coordinator, Fundamentals of Science profile area Leiden University

M. Franx

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

H. Röttgering

- Member, board of directors of the faculty of Science

J. Schaye

- Member, WeCo (Permanent Committee for Academic Practice)

I. Snellen

- Member, Student travel fund panel of Leiden University Fund LISF

P. vd Werf

- Organist Academy Auditorium

Science policy functions of Observatory members

Rychard Bouwens

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

Bernhard Brandl

- PI, METIS (mid-IR instrument for the E-ELT)
- Deputy co-PI MIRI (mid-IR instrument for the JWST)
- co-I KINGFISH Herschel Open Time Nearby Galaxies Key Project
- Member, ESO Contactcommissie
- Member, review board, BMBF Verbundforschung
- Member, time allocation committee, DLR
- Member, Evaluation Board, Leibniz Gesellschaft
- Member, NOVA Instrument Steering Committee (ISC)
- Member, DAG (Turkish 4m telescope) advisory board
- Associate, ESFRI board

Jarle Brinchmann

- ESO Working group for a spectroscopic survey telescope: Member
- JWST Data Processing Working Group: Member
- Euclid Galaxy & AGN Evolution Science Working Group: co-Chair
- Euclid Consortium: member, co-coordinator of all aspects of legacy science.
- Euclid COMS Group: Member, responsible for newsletter
- Euclid Calibration Working Group: Member
- Euclid Consortium Survey Working Group: Member
- Euclid Archive User Group: Member
- Euclid Consortium Diversity Committee: Member
- MUSE Science Team: Member (builder status)
- MUSE Data management group: Chair

Anthony Brown

- Chair, Gaia Data Processing and Analysis Consortium
- Member, Gaia Science Team
- PI Gaia/Netherlands
- Vice President, IAU Commission 8
- President, IAU Commission A1
- Member, Steering Committee IAU Division A
- Associate Member, International Earth Rotation and Reference Systems Service
- Member, IAU Commission 37
- Member, EU Marie-Curie ITN Gaia Research for European Astronomy Training (GREAT)
- Member, Executive Board GENIUS FP7-Space Collaborative Project
- Member, Steering Committee ESF-RNP Gaia Research for European Astronomy Training (GREAT)

Ewine van Dishoeck

- Scientific Director, Netherlands Research School for Astronomy (NOVA)
- President-elect, IAU
- Co-Editor, Annual Reviews of Astronomy & Astrophysics
- Member, ESA Space Sciences Advisory Committee (SSAC)
- Member, NWO Gebiedsbestuur Exacte Wetenschappen (GB-E)
- Member, NWO Permanente Commissie Grootschalige Wetenschappelijke Infrastructuur
- Member, National Committee on Astronomy (NCA)
- Chair, KNAW Large Research Infrastructures agenda
- Chair, Harvard astronomy department visiting committee
- Chair, ERC Advanced Grants PE9 panel
- Co-PI, European JWST-MIRI consortium
- President, IAU Division H Interstellar Matter and the Local Universe
- Coordinator, Herschel-HIFI WISH Key Program

Marijn Franx

- Member, KNAW sectie physics and astronomy
- Member, KNAW domein jury
- Member, James Webb Space Telescope Science Working Group
- Member, NIRSPEC Instrument Science Team
- Member, 3DHST team
- Member, Lega-C team
- co-PI, Ultravista Survey
- Member, MUSE Science Team

Jacqueline Hodge

- Co-chair of the Next Generation Very Large Array (ngVLA) High-redshift Universe working group
- Co-chair of the VLA Sky Survey Extragalactic Working Group

Henk Hoekstra

- Deputy coordinator NOVA network 1
- Member NWO Vidi grant selection committee
- Member ESO Observing Program Commitee (vice-chair)
- Member Lorentz Center Astronomy Advisory Board
- Member Euclid Consortium Coordination Group
- Member Euclid Consortium Editorial Board
- Euclid Cosmology Science Coordinator
- Member Athena Mission

Michiel Hogerheijde

- Program director, Netherlands node ALMA Regional Center
- Member, MATISSE Science Group
- Member, Board of Directors Leids Kerhoven-Bosscha, Oort, and LeidsSterrewacht Foundations
- Member, ALMA Regional Center Coordinating Committee
- Member, Scientific Organizing Committee, 6th Zermatt ISM Symposium 'Conditions and impact of starformation: from lab to space'

Christoph Keller

- Member of the NWO VIDI grant selection committee
- Member of the EPA Network Task Group on Citizen Science, European Environmental Agency, Copenhagen, Denmark
- Member of the Project Science Team, European Extremely Large Telescope, ESO
- Chair, member of the Board, Isaac Newton Group of Telescopes, Canary Islands, Spain
- Co-Chair, Planetary and Exoplanetary Science network, NL Science Foundation (NWO)
- Member of the Editorial board, Astronomische Nachrichten

Matthew Kenworthy

- ING Science TAC
- High Contrast Imaging manager for METIS
- High Contrast Imaging lead for ERIS (VLT thermal infrared imager)
- ESO Users Committee
- NSF reviewer

Koenraad Kuijken

- Scientific Delegate from the Netherlands, ESO Council
- Chair, ESO contact committee
- Member and Vice-chair, Netherlands Committee for Astronomy
- 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)

Harold Linnartz

- Vice chair division XII / IAU commission 14 / working group solids and their surfaces
- Theme coordinator NWO-EW/CW 'DAN' (Dutch Astrochemistry Network): Solid state astrochemistry
- Theme coordinator NWO-PEPSCI (Planetary and Exo-planetary Science): biomarkers
- Member SOC biannual ‘Molecular High Resolution Spectroscopy Symposium’
- Member SOC ‘IR Plasma Spectroscopy Meetings’
- Member SOC ‘Laboratory Astrophysics Session’, IAU GA Honolulu 2015
- Member SOC 'ECLA2016' (European Conference on Laboratory Astrophysics)
- Chair Lorentz Workshop 'SWEDIBLES' (on diffuse interstellar bands)
- Chair Lorentz Workshop 'ICE AGE - the ERA of JWST'
- Workgroup leader, FOM group FOM-L-027
- Member, NWO-CW 'Spectroscopy and Theory'
- Member, HRSMC research school

Jan Lub

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

Frans van Lunteren

- Committee on Meetings and Programs of the American History of Science Society
- Advisory Editor Isis (Journal of the History of Science Society)
- Chairman board Foundation Historical Committee Leiden University
- Chairman board Foundation Siegenbeek van Heukelom, Leiden
- Editorial board Nederlands Tijdschrift voort Natuurkunde
- Advisory board Foundation for Lorentz & Einstein Media Research
- Science Committee Teylers Museum
- Writer-in-residence Committee Leiden University
- Studium Generale Committee Leiden University
- Chairman jury Boerhaave biografieprijs 2015
- Organizing committee Woudschoten conference 'Material cultures of science'
- Selection Committee Clusius Chair Leiden University
- PhD Committee Bart Karstens, Philosophyn Department, Leiden University

- Confidential Counsellor for Academic Integrity Issues of the Science Faculty VU
- Koninklijke Hollandse Maatschappij van Wetenschappen
- Teylers Tweede Genootschap Haarlem

Simon Portegies Zwart

- Visiting senior scientist at RIKEN (Kobe, Japan)
- 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

Elena Rossi

- NWO Veni committee member
- Member of the CAN committee for Astroparticle Physics research in the Netherlands
- Leader of LOFT (Large Observatory for X-ray timing) science definition working group on "Tidal Disruption events (TDE)" (leader of the TDE white book chapter)
- Co-Leader of the SKA (Square Kilometre Array) science definition working group on "Tidal Disruption events" (leader of the TDE white book chapter)
- Leader of the XIPE mission (the X-ray imaging polarimeter explorer) working group on ``Tidal Disruption events"
- Member of the eLISA (Evolved Laser Interferometer Space Antenna) consortium and working group on "Supermassive black hole formation and evolution" and on "white dwarf science"

Huub Röttgering

- PI, LOFAR surveys: Opening up a new window on the Universe
- Member, Science Advisory Committee ASTRON
- Member, Board LOFAR International Telescope
- Member, SKA Science working group on radio continuum surveys
- Member, NL-SKA contact committee
- Member, NOVA board
- Member, Board Holland Space Cluster
- Chair, ALMA Proposal Review panel for Cosmology
- Member, XMM, Proposal Review panel for Cosmology
- Chair, Euclid consortium board

Joop Schaye

- PI, OWLS collaboration (OverWhelmingly Large Simulations)
- PI, MUSE survey of QSO absorbers
- 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, "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''

Ignas Snellen

- Member SOC, 20 Years of giant Exoplanets (Obs. Haute Provence)
- Member SOC, Who's who? From Super-Earths to Brown Dwarfs (Paris)
- Panel chair, ESO Observation Programme Committee (OPC)
- PI, Multi-site All-Sky CAmeRA, MASCARA
- EU FP7 Network progress reviewer
- Member, Editorial Board, Zenit – Dutch amateur astronomy magazine
- Member, Board of Dutch Astronomical Society (NAC)

- Member, Co-I of HARPS3@INT project
- Member, PLATO mission consortium
- Member, METIS Science Team
- Member ESA ARIEL Consortium

Xander Tielens

- Chair Science Advisory Committee SRON
- Coordinator Dutch Astrochemistry Network
- Jurylid KNAW Onderwijsprijs

Paul van der Werf

- Principal Investigator, JCMT Cosmology Legacy Survey
- Principal Investigator, Herschel Comprehensive (U) LIRG Emission 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

Malcolm Fridlund

- Panel Chair, ESO Observing Program Committee

Jelle 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)

Raymond Oonk

- LOFAR Users Committee
- Advisory committee for the (LOFAR) Calibration and Imaging Tiger Team
- Herschel Data Products Users Group

Euan Monaghan

- Royal Astronomical Society Membership Committee
- Royal Astronomical Society International Committee
- Astrobiology Society of Britain Committee

Huib Jan van Langevelde

- Member consortium board of directors European VLBI Network
- Member RadioNet Board and Executive Board
- Member of the ASTERICS 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”
- Chair of the SKA Consortium Board for Signal and Data Transport (SaDT)

Grants

P.I.	Funder	Proposal Title	Grant
Schaye	NWO VICI	How do galaxies regulate their growth?	1500 k€
Snik	ERC starting grant	Forging advanced Liquid-Crystal Coronagraphs Optimized for Novel Exoplanet Research	1500 k€
van Langevelde	ASTRON / JIVE	The Galactic Bar in terms of orbiting AGB stars	100 k€
De Gasperin	NWO VENI	Galaxy Clusters at the lowest frequencies	250 k€
Candian	NWO VENI	The Inventory of Large Molecules in Protoplanetary Disks	250 k€
Keller/Snik	STW	FlySPEX: development of a commercial, high-accuracy spectro-polarimetric sensor-head	135 k€
Brown/de Zeeuw	ESO/ESTEC	Structure and star formation history of the Orion region from early Gaia data releases	100 k€
Portegies Zwart	ComPat	Computing Patterns for High Performance Multiscale Computing	426 k€
Miley/Brinchmann	EPN2010-RI	EUROPLANET 2020 Research Infrastructure	50 k€
Röttgering		WEAVE	35 k€
Labbé	Crowdfunding	Breng de zon naar Leiden	20 k€
Kenworthy	FAPESP	AO Development for Extremely Large Telescopes	294 k€
Doelman/Kenworthy	TNO-Connexi	Contrast enhancement for Exoplanet Imaging	60 k€
Doelman/Keller	TNO-Connexi	Non-linear control of adaptive optics for exoplanet imaging	170 k€

ANNUAL REPORT /15

Research Institute Leiden Observatory

Onderzoekinstituut Sterrewacht Leiden

Sterrewacht Leiden

Universiteit Leiden
The Netherlands

Ingrid van Houten-Groeneveld (1921 - 2015)
and Kees van Houten (1920 - 2002)

Ingrid van Houten – Groeneveld

1921 - 2015

On March 30 2015 Ingrid van Houten passed away at the age of 93 at the care home Wijckerslooth in Oegstgeest close to Leiden, after a whole life dedicated to 'die kleinen Planeten'.

We can do no better than quote her own description of her professional life, which she prepared for the Astronomische Gesellschaft in 2013.

"Born 21.10.1921 in Berlin, Germany, studied at the university of Heidelberg. February 1944 after promotion research assistant at the Sternwarte Heidelberg. After the war part time at Astronomisches Rechen-Institut in Heidelberg. From 1948 till about 1951 together with Prof. A. Bohrmann et al. for "the catalogue of accurate positions of faint stars" with Meridian circle. Then finding and identifying asteroids from circa 1950 on."

In 1952 Dr. G. P. Kuiper needed help for his McDonald-survey of Minor Planets. The purpose was to photograph a ring along the ecliptic for about 15 months, to photograph all known asteroids till about 16th magnitude. The magnitudes should be determined by photographing Selected Area fields with correct established magnitudes. Till this time every observer had his own magnitude system. Tom Gehrels was responsible to determine the absolute magnitudes of all about 2000 asteroids known around 1950. I had experience in the searching and identifying the objects. From 1952 till 1954 I was in Yerkes Observatory. My successor for the McDonald survey became C.J. van Houten from Leiden Observatory.

In November 1955 I came back to Yerkes to help finishing the work and writing the article. Kees (Dutch abbreviation of Cornelis) and I observed rotational periods of asteroids. But before we left the States we decided to marry (in Germany), both of us being 'Europeans' in USA.

In 1957 I came to Leiden where I worked on the 1/a-values of the comets used by J.H. Oort in his study of their distribution. At that time, one still had to make the numerical integrations with the old table-calculators instead of computers. In 1960 we started the Palomar-Leiden-Survey together with G.P. Kuiper, T. Gehrels, P. Herget and B.G. Marsden, followed in 1971, 1973, 1977 by 3 Trojan-Surveys."

This summarizes, but hardly does justice to her activities in the field of minor planets for almost 65(!) years, most of them together with her husband Kees van Houten, until his death in 2002. Together they discovered over 5000 minor planets, an all time record only surpassed by modern automatic surveys. As a married woman she never held a paid appointment after leaving the USA., which makes this result even more remarkable. This lack of formal recognition, which today we would consider an injustice, never appeared to affect her dedication to astronomy, astronomers and students.

Many of us, at all professional levels, have experienced her kindness and support in difficult moments. Ingrid had strong convictions and was always urging to do things right. On many occasions she was the first to notice when a student was in trouble, and then she would give all her support.

After Kees' death she lovingly and with great care took it upon her to prepare for publication his large collection of photoelectric five-colour (Walraven) measurements of eclipsing binaries and OB stars in the southern Milky Way. She kept taking part in the observatory life until walking became to difficult for her a few years ago.

In 2006 Leiden Observatory organized a small symposium in her honor on the occasion of her 85th birthday.
This gave her a final opportunity to see many 'old' friends still active in her field.

She is survived by her son Karel, his wife Thea and their two daughters Caroline and Irene.

ANNUAL REPORT /15

Research Institute Leiden Observatory

Onderzoekinstituut Sterrewacht Leiden

Sterrewacht Leiden

Universiteit Leiden
The Netherlands